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RISK CHARACTERIZATION HANDBOOK

Prepared for the U.S. Environmental Protection Agency by members of the Risk Characterization Implementation Core Team, a group of EPA's Science Policy Council

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TABLE OF CONTENTS

FOREWORD . . . . . Page vii

ACKNOWLEDGMENTS . . . . . Page x

OVERVIEW OF THIS RISK CHARACTERIZATION HANDBOOK . . . . . Page 1
Outline of the Basic Structure of the Risk Characterization Guide . . . . . Page 2

RISK CHARACTERIZATION GUIDE . . . . . Page 3

1. INTRODUCTION TO RISK CHARACTERIZATION . . . . . Page 5
1.1 Overview . . . . . Page 5
1.2 Understanding Risk Characterization . . . . . Page 10
1.2.1 What is Risk Characterization? . . . . . Page 10
1.2.2 Are Risk Characterizations Written As Part of Ecological Risk Assessments Different from Those Written As Part of Human Health Risk Assessments? . . . . . Page 11
1.2.3 Are Risk Assessment and Risk Characterization the Same? . . . . . Page 13
1.2.4 Are Risk Characterization and Risk Communication the Same? . Page 13
1.2.5 What is the Value of Risk Characterization in the Regulation Development Process? . . . . . Page 13
1.2.6 What Role does Risk Characterization have in Regulatory Negotiations? . . . . . Page 14
1.2.7 Do Risk Characterizations Need Peer Review? . . . . . Page 14
1.3 Risk Characterization Principles . . . . . Page 14
1.3.1 What are Criteria for Transparency? . . . . . Page 15
1.3.2 What are Criteria for Clarity? . . . . . Page 16
1.3.3 What are Criteria for Consistency? . . . . . Page 17
1.3.4 What are Criteria for Reasonableness? . . . . . Page 18
1.4 Overview Presentation of TCCR Principles . . . . . Page 19
1.5 The Roles of People and Organizations in Risk Characterization . . . . . Page 20
1.5.1 Who is Ultimately Accountable for Risk Characterization? . . . . . Page 20
1.5.2 Who Are the Agency Staff Involved in Risk Characterization? . . Page 20
1.5.3 What Are My Responsibilities as a Risk Assessor? . . . . . Page 20
1.5.4 What Are My Responsibilities as a Risk Manager? . . . . . Page 22
1.5.5 What Does the Risk Characterization Policy Tell Risk Assessors? . . . . . Page 24

1.5.6 How Will Risk Characterization Help the Risk Assessor? . . . . . Page 24
1.5.7 How Will Risk Characterization Help the Risk Manager? . . . . . Page 24
1.5.8 Which Office/Region or Other Agency is Responsible for Writing the Risk Characterization? . . . . . Page 25
1.5.9 What is the Responsibility of Organizations that Submit Risk Assessments to EPA? . . . . . Page 25
1.5.8 What is the Role of the Science Policy Council (SPC)? . . . . . Page 26

2. PREPARING FOR A RISK ASSESSMENT AND ITS RISK CHARACTERIZATION – PLANNING AND SCOPING . . . . . Page 27
2.1 Overview . . . . . Page 27
2.2 Planning and Scoping . . . . . Page 27
2.2.1 What Should You Discuss During Planning and Scoping? . . . . . Page 28
2.2.2 Should the Planning and Scoping Discussion Focus on What the Risk Assessment Results Should Be? . . . . . Page 29
2.2.3 What are Possible Products Emerging from Planning and Scoping? . . . . . Page 29
2.2.4 What Are the Benefits of Planning and Scoping? . . . . . Page 30
2.2.5 Who Does Planning and Scoping? . . . . . Page 31
2.2.6 When Does the Risk Assessor/Risk Manager Dialog End? . . . . . Page 31
2.3 Typology for Risk Characterization . . . . . Page 31

3. ELEMENTS OF A RISK CHARACTERIZATION . . . . . Page 35
3.1 Overview . . . . . Page 35
3.2 Elements of a Risk Characterization . . . . . Page 35
3.2.1 Can a “Bright Line” or Number be the Risk Characterization? . . . Page 36
3.2.2 What Key Information Needs to Be Identified During the Risk Assessment Process to Prepare for Risk Characterization? . . . . . Page 37
3.2.3 How Do I Put the Risks Estimated in this Assessment into a Context with Other Similar Risks? . . . . . Page 37
3.2.4 How Do I Address Sensitive Populations, Ecosystems and Species? . . . . . Page 38
3.2.5 What are Scientific Assumptions and How Do I Address Them? . . . . . Page 39
3.2.6 What Are Policy Choices and How Do I Address Them? . . . . . Page 40
3.2.7 How Do I Address Variability? . . . . . Page 40
3.2.8 How Do I Address Uncertainty? . . . . . Page 40
3.2.9 How Do I Address Bias and Perspective? . . . . . Page 41
3.2.10 How do I Address Strengths and Weaknesses? . . . . . Page 41

3.2.11 What Are the Major Conclusions to Carry Forward? . . . . . Page 42
3.2.12 How Do I Describe the Alternatives Considered? . . . . . Page 43
3.2.13 How Do I Address Research Needs? . . . . . Page 43
3.3 Should Decisions be Delayed Until Research is Completed? . . . . . Page 44

4. RISK CHARACTERIZATION-RELATED PRODUCTS . . . . . Page 45
4.1 Overview . . . . . Page 45
4.2 Products of Risk Characterization . . . . . Page 45
4.2.1 What is the Technical Risk Characterization? . . . . . Page 46
4.2.2 What are Risk Characterization Products I Can Prepare for Risk Managers? . . . . . Page 46
4.2.3 What are Risk Characterization Products I Can Prepare for Other Audiences, Like the Public? . . . . . Page 47
4.3 Audiences for Risk Characterization Products . . . . . Page 47
4.3.1 Who Are the Audiences for Risk Characterization Products? . . . . Page 47
4.3.2 Can I Use a Single Risk Characterization Product for All Audiences? . . . . . Page 48
4.3.3 How Much Technical Detail is Needed for Different Audiences? . . . . . Page 48
4.3.4 How Do I Ensure that the Irreducible Set of Risk Characterization Information is Carried Forward in All Risk Characterization Products? . . . . . Page 49
4.4 Risk Characterization Format and Length . . . . . Page 49
4.4.1 Is There a Standard Format for a Risk Characterization? . . . . . Page 49
4.4.2 What is an Appropriate Length for a Risk Characterization? . . . . Page 50

5. INFORMING DECISION MAKERS . . . . . Page 51
5.1 Overview . . . . . Page 51
5.2 Science in Decision Making . . . . . Page 51
5.2.1 Is the Risk Assessment the Single Driving Force Behind Decision Making? . . . . . Page 51
5.3 Decision-Making Factors . . . . . Page 51
5.3.1 What Are the Major Factors that Affect Decision Making? . . . . . Page 51
5.4 Characterization of Non-Science Factors . . . . . Page 54
5.4.1 Are the Economic and Other Non-Risk Assessments Subject to Characterization? . . . . . Page 54
5.4.2 Can the Principles of TCCR Apply to Characterizations of the Other Factors? . . . . . Page 54

6. ADMINISTRATIVE ISSUES . . . . . Page 55
6.1 Overview . . . . . Page 55
6.2 Risk Characterization Record . . . . . Page 55
6.2.1 What is the Risk Characterization Record? . . . . . Page 55
6.2.2 How Can the Risk Characterization Record Improve the Risk Characterization Process? . . . . . Page 55
6.2.3 Where Should the Risk Characterization Record be Kept and For How Long? . . . . . Page 56
6.3 Budget Planning . . . . . Page 56
6.4 Legal Considerations . . . . . Page 56
6.4.1 Are There Legal Ramifications from the Risk Characterization Policy? . . . . . Page 56
6.4.2 Is Legal Advice Needed? . . . . . Page 56
6.5 Peer Review of Risk Characterization Handbook . . . . . Page 57

SUBJECT INDEX . . . . . Page 59

COMMONLY USED ACRONYMS . . . . . Page 61

APPENDIX A . . . . . Page A-1
POLICY FOR RISK CHARACTERIZATION . . . . . Page A-1

APPENDIX B . . . . . Page B-1
WAQUOIT BAY CASE STUDY . . . . . Page B-1

APPENDIX C . . . . . Page C-1
GENERIC KETONE CASE STUDY . . . . . Page C-1

APPENDIX D . . . . . Page D-1
MITEC CASE STUDY . . . . . Page D-1

APPENDIX E . . . . . Page E-1
MIDLOTHIAN CASE STUDY . . . . . Page E-1

APPENDIX F . . . . . Page F-1
References Concerning Risk Characterization . . . . . Page F-1
References of EPA Risk Assessment Guidelines . . . . . Page F-2

FOREWORD

This Handbook was prepared by the Science Policy Council (SPC) for EPA staff and managers and others as a guide to Risk Characterization. It implements EPA's March 1995 Risk Characterization Policy which improved on the foundation of the February 1992 Agency-wide policy for risk characterization. Both the 1992 and 1995 documents point out that "... scientific uncertainty is a fact of life (and) ... a balanced discussion of reliable conclusions and related uncertainties enhances, rather than detracts, from the overall credibility of each assessment …". Both also note that while the role of science to inform but not make decisions is widely recognized in EPA, and in the larger risk assessment and regulatory community, these communities often use the risk assessment number as the stated reason for decisions, not always clearly highlighting the legal, economic, social and other non-scientific issues that also go into the decision.

From the start it was recognized that implementation of this policy would require a culture change at EPA and that achieving an Agency-wide culture change would not be effective if imposed from the top down. Thus, every effort was made to engage career EPA employees, including risk assessors, risk managers and senior decision-makers across the Agency to help implement the policy. The effort was monumental, directly involving several hundred Agency employees in all Offices and Regions. A Risk Characterization Implementation Team was established with members from each Region and Program Office, including the Office of General Counsel, to guide and direct the initial efforts to implement the policy.

During the dialog that led to the decision to prepare a single guidance document, the SPC heard from the Programs and Regions about the need for tools and case studies to make the guidance understandable and assure consistent implementation. This Handbook provides a single, centralized body of risk characterization implementation guidance for Agency risk assessors and risk managers to help make the risk characterization process transparent and the risk characterization products clear, consistent and reasonable (TCCR). TCCR became the underlying principle for a good risk characterization. The elements of a risk characterization (among them, for example, key findings, policy choices, uncertainty and variability) describe in a straight-forward fashion the critical points that a good risk characterization should contain to make it valuable in any Agency risk assessment.

> ***"If I send a man to buy a horse for me, I expect him to tell me that horse's points -- not how many hairs he has in his tail."***
> ***Abraham Lincoln***

This Handbook has two parts. The first is the Risk Characterization guidance itself. The second part comprises the Appendices which contain the Risk Characterization Policy, the risk characterization case studies and references.

As mentioned earlier, hundreds of people from across the Agency were instrumental in the preparation of this Handbook, guided by the SPC and its Risk Characterization Team. They were essential in bringing this effort to fruition. In addition, I want to give a special acknowledgment to the principal authors, Jack Fowle and Kerry Dearfield -- their hard work and persistence made this Handbook a reality. I also want to recognize the thoughtful and helpful input that the recently retired Executive Director of the Science Policy Council, Dr. Dorothy Patton, provided. The Agency is indebted to her for her guidance, patience and support.

It is with great pleasure that I present the Risk Characterization Handbook.

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Other individuals were instrumental in creating the case studies:

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U.S. Environmental Protection Agency

OVERVIEW OF THIS RISK CHARACTERIZATION HANDBOOK

The Risk Characterization Handbook is created as a single, centralized body of risk characterization implementation guidance for Agency risk assessors and risk managers. The Risk Characterization Policy calls for a **transparent** process and products that are **clear**, **consistent** and **reasonable**. All risk assessments have a risk characterization product, but effective characterization depends on **t**ransparency, **c**larity, **c**onsistency and **r**easonableness (**TCCR**). TCCR is the key to a successful risk characterization.

Effective characterization depends on Transparency, Clarity, Consistency and Reasonableness (TCCR)

This Handbook is divided into two parts:

1. Risk Characterization Guide

The Risk Characterization Guide is designed to provide risk assessors, risk managers, and other decision-makers an understanding of the goals and principles of risk characterization, the importance of planning and scoping for a risk assessment, the essential elements to address in a risk characterization, the factors that are considered in decision making by risk managers, and the forms the risk characterization takes for different audiences. A discussion of the various administrative details regarding risk characterization completes the guide.

The following page provides an outline and a table describing the basic structure of the risk characterization guide.

2. Appendices

The Appendices contain the Risk Characterization Policy and case studies. The case studies contain examples of risk characterizations from risk assessments that apply the principles described in the Risk Characterization Guide. A list of references is also provided for your use.

Outline of the Basic Structure of the Risk Characterization Guide

- **Chapter 1** provides all audiences with an introduction to risk characterization in general, including details of TCCR.
- **Chapters 2 – 4** describes a continuous process from planning and scoping to final products from the risk characterization. The table below shows this basic flow of work and where the risk assessment guidelines fit into this continuum.
- **Chapter 5** briefly discusses for all audiences the role of science and risk assessment in the decision-making process.
- **Chapter 6** describes for Agency risk assessors and risk managers their essential roles and activities.

	CHAPTER 2	RISK ASSESSMENT GUIDELINES *	CHAPTER 3	CHAPTER 4	
PRODUCTS	⇨⇨ • Planning and Scoping • Conceptual Model • Analysis Plan	⇨ . . . . . ⇨⇨ • Hazard Identification • Dose Response Assessment • Exposure Assessment	⇨ . . . . . ⇨⇨ • Risk Characterization including Integrated Analysis	⇨ . . . . ⇨⇨ • Summaries	⇨ • Communication Pieces
AUDIENCE	• Risk Managers • Risk Assessors	• Risk Assessors ↕ dialog • Risk Managers	• Peer Reviewers • Risk Assessors	• Risk Managers	• Public
PEER REVIEW	• These parts can be candidates for peer review	• Pieces can be candidates for peer review	• Usually a major work product for peer review		

* The Risk Assessment Guidelines are not covered by this Handbook. They are mentioned in this table because they are part of the overall risk assessment process at EPA.

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RISK CHARACTERIZATION GUIDE

1. INTRODUCTION TO RISK CHARACTERIZATION

1.1 Overview

To help inform its decision making, the United States Environmental Protection Agency (U.S. EPA) evaluates environmental risks through an assessment process that involves a substantial body of scientific data and analysis with much judgment and uncertainty. EPA has published guidelines to steer the Agency's evaluation of the risks from exposure to environmental agents (see references for EPA Risk Assessment Guidelines at the end of this document). These evaluations culminate in a characterization of the risks. Our understanding of risk characterization has evolved over many years.

The first major reference to risk characterization is found in the 1983 National Academy of Sciences' (NAS') National Research Council (NRC) publication Risk Assessment in the Federal Government: Managing the Process (commonly referred to as the "Red Book"). Risk characterization is defined as

> "... the process of estimating the incidence of a health effect under the various conditions of human exposure described in exposure assessment. It is performed by combining the exposure and dose-response assessments. The summary effects of the uncertainties in the preceding steps are described in this step."

In this definition, ways to make the risk assessment process transparent are not fully developed or apparent.

The following year, in 1984, EPA published Risk Assessment and Management: Framework for Decision-Making where risk characterization is described as the place where

> "… finally we estimate the risk associated with the particular exposures in the situation being considered for regulation. While the final calculations themselves are straight forward (exposure times potency, or unit risk) the way in which the information is presented is important. The final assessment should display all relevant information pertaining to the decision at hand, including such factors as the nature and weight of evidence for each step of the process, the estimated uncertainty of the component parts, the distribution of risk across various sectors of the population, the assumptions contained within the estimates and so forth."

While arriving at the risk assessment number is stressed, more emphasis is placed on making the risk assessment process transparent, on a fuller description of the strengths and weaknesses of the assessment, and on providing plausible alternatives within the assessment.

Concerns over adequately characterizing risk to maintain the public's perception of and confidence in EPA's risk assessments led former Deputy Administrator Henry Habicht to issue an Agency-wide policy for risk characterization on February 26, 1992. He noted that

> "... scientific uncertainty is a fact of life (and) ... a balanced discussion of reliable conclusions and related uncertainties enhances, rather than detracts, from the overall credibility of each assessment …"

In its 1992 publication "Improving Risk Characterization" the American Industrial Health Council (AIHC) recommended ways to improve risk characterization. AIHC recommended the following steps:

a) Identify potential users of risk characterization at the beginning of the risk assessment process

b) Identify the types of decisions that need to be made early in the process

c) Make the content of the assessment relevant to the diversity of potential decisions by including in the technical content of the risk characterization wherever possible, several dimensions and estimates of risk

d) Ensure periodic two-way communication between assessors and users during the risk assessment process

e) Conduct future research and systematic study "... on the effectiveness of risk characterization messages and approaches, on ways of improving 'risk literacy' of users of assessments, on the process of integration of technical information about risk with information on other social values, so that social dimensions of risk are recognized as legitimate parts of the risk management decision and are accounted for in the risk characterization."

In this definition, the focus of risk characterization shifted from an emphasis on the purely technical aspect of combining exposure and dose-response information to arrive at a risk assessment number to the importance of the social aspects of risk assessment. Conversations between risk assessors and users of risk assessment from the beginning and throughout the risk

assessment process are needed to ensure that risk assessors understand the needs of decision-makers to communicate the results of the risk assessment to those who are affected by the risk management decision.

In 1994 in Science and Judgment, the NAS returned the focus to the original concept of risk characterization. The NAS defined it as

> "... the integration of information from the first three steps of the risk assessment process, as defined in the 1983 NAS 'Redbook', to develop a qualitative estimate of the likelihood that any of the hazards associated with the agent of concern will be realized in exposed people. This is the step in which risk assessment results are expressed. Risk Characterization should also include a full discussion of the uncertainties associated with the estimates of risk."

Administrator Carol Browner reaffirmed the central role of risk characterization for the Agency on March 21, 1995 when she issued the Agency-wide Risk Characterization Policy (found in Appendix A). The Policy calls for all risk assessments performed at EPA to include a risk characterization to ensure that the risk assessment process is transparent and that the risk assessments are clear, reasonable and consistent with other risk assessments of similar scope prepared by programs across the Agency. Effective risk characterization is achieved through **t**ransparency in the risk assessment process and **c**larity, **c**onsistency, and **r**easonableness of the risk assessment product (TCCR).

In their 1996 report Understanding Risk, the NAS extended their definition of risk characterization. The NAS defined it as

> "... a synthesis and summary of information about a potentially hazardous situation that addresses the needs and interests of decision makers and of interested and affected parties. Risk characterization is a prelude to decision making and depends on an iterative, analytic-deliberative process." They go on to refer to risk characterization as "the process of organizing, evaluating and communicating information about the nature, strength of evidence and the likelihood of adverse health or ecological effects from particular exposures."

Here the NAS places equal emphasis on fully characterizing the scope, uncertainties, limitations, and strengths of the assessment and on the social dimensions of interacting with decision makers and other users of the assessment in an iterative, analytic-deliberative process. The purpose of this process is to ensure that the assessment will be useful for the purposes for which it is intended and that it will be understandable.

The Presidential Commission on Risk Assessment and Risk Management (CRARM) was created by the Clean Air Act Amendments of 1990 and formed in 1994. Its Congressional mandate was to develop more scientific use of risk-based methods and specifically to provide guidance on how to deal with residual emissions from Section 112 hazardous air pollutants after technology-based controls have been placed on stationary sources of air pollutants. In 1997, the Commission published its report in two volumes (CRARM, 1997a; CRARM,1997b) and also wrote about the importance of risk characterization to better understand and quantify risks as well as to evaluate strategies to reduce human and ecological risks. They noted that

> "risk characterization is the primary vehicle for communicating health risk assessment findings. Many risk characterizations have relied primarily on mathematical estimates of risk to communicate risk assessment findings, often conveying an unwarranted sense of precision while failing to convey the range of scientific opinion. They are particularly difficult for audiences unfamiliar with risk assessment to comprehend. Effective risk management is impeded without effectively communicating information about who is at risk, how they might be affected, what the severity and reversibility of adverse effects might be, how confident the risk assessors are in their predictions and other qualitative information that is critical to decision-making."

EPA's risk characterization efforts build on its own 1995 Risk Characterization Policy, NAS, President's Commission, AIHC and others' concepts as well as on the Agency's understanding that risk assessments provide important information about the nature, magnitude and likelihood of possible environmental risks to inform decisions. By August 1995, EPA Program Offices and Regions drafted Risk Characterization Implementation Plans to guide the development of risk characterizations done in each Office/Region. Over the next two years, a series of colloquia for risk assessors and roundtables for risk managers was held to test these draft Implementation Plans against case studies, and to work out just what it takes to adequately characterize risk. Over 200 EPA employees participated in these events, sharing their office's culture and their own experiences and perspectives about risk characterization with other EPA staff whose offices' cultures and whose personal experiences and perspectives were often different.

The Agency recognized that a culture change is needed at EPA if the Agency is to successfully implement the Risk Characterization Policy which describes a philosophy of **t**ransparency, **c**larity, **c**onsistency, and **r**easonableness or **TCCR** as coined in the first colloquium. The TCCR philosophy needs to be practiced in the everyday work of EPA as the different products (e.g., reports, briefings etc.) flowing from Agency risk assessments are developed to translate risk assessment findings for managers and the public.

Risk characterization at EPA assumes different levels of complexity depending on the nature of the risk assessment being characterized. The level of information contained in each risk characterization varies according to the type of assessment for which the characterization is written and the audience for which the characterization is intended. The goal of risk characterization is to clearly communicate the key findings and their strengths and limitations so its use in decision making can be put into context with the other information critical to evaluating options for rules, regulations and negotiated agreements (e.g., economics, social values, public perception, policies, etc.). EPA's concept of risk characterization has evolved since March 1995 to build on the experience of Agency risk assessors and managers and on the AIHC, President's Commission, and the NAS Understanding Risk definitions. Risk characterization at EPA is considered to be a conscious and deliberate process to bring all important considerations about risk, both the likelihood of the risk but also the strengths and limitations of the assessment and a description of how others have assessed the risk into an integrated picture. As an integrated picture, the risk characterization focuses on how those components interact.

It should be noted that most of the emphasis in the discussion about risk characterization generally focused on human health risk assessments. It is well recognized that the general principles for risk assessment and risk characterization apply equally to ecological risk assessments. Efforts at EPA culminated in the publication of risk assessment guidelines for ecological risk assessment. Included in these guidelines is a discussion on risk characterization for ecological risk assessments. This Handbook also builds on this effort.

Based on the experiences of those attending the meetings and using these various documents to help characterize risk across the Agency since 1995, a single Agency-wide document was determined to be needed. The Risk Characterization Handbook in general supersedes the original Guidance and its associated "Elements Document" issued with the Risk Characterization Policy. However, some of the more technical aspects of the original Guidance which are not covered specifically in this Handbook (e.g., Section III - Exposure Assessment and Risk Descriptors in the 1995 Guidance) are still appropriate. Furthermore, the Handbook coalesces the ideas and directions found in the draft Implementation Plans and also supersedes those plans. However, Agency offices and regions may wish to prepare tailored guidance that meets their individual needs to supplement and remain consistent with the information in this Handbook (e.g., Risk Assessment Guidance for Superfund: Volume I – Human Health Evaluation Manual (RAGS/HHEM)).

1.2 Understanding Risk Characterization

1.2.1 What is Risk Characterization?

Risk characterization is an integral component of the risk assessment process for both ecological and health risks, i.e., it is the final, integrative step of risk assessment. As defined in the Risk Characterization Policy (Appendix A), ***the risk characterization integrates information from the preceding components of the risk assessment and synthesizes an overall conclusion about risk that is complete, informative, and useful for decision makers***. In essence, a risk characterization conveys the risk assessor's judgment as to the nature and existence of (or lack of) human health or ecological risks.

For health risk assessment, the NAS describes a four step paradigm (NRC, 1983). For each step, the relevant and scientifically reliable information is evaluated. In addition, the related uncertainties and science policy choices are described.

a) Hazard Identification -- the determination of whether a particular chemical is or is not causally linked to particular health effects

b) Dose-Response Assessment -- the determination of the relation between the magnitude of exposure and the probability of occurrence of the health effects in question

c) Exposure Assessment -- the determination of the extent of human exposure before or after application of regulatory controls

d) Risk Characterization -- the description of the nature and often the magnitude of human risk, including attendant uncertainty

In 1998, EPA published risk assessment guidelines for ecological risk assessment (USEPA, 1998), calling for:

a) Problem Formulation -- the evaluation of goals, selection of assessment endpoints, preparation of the conceptual model, and development of an analysis plan

b) Analysis -- the evaluation of exposure to stressors and identification of the relationship between stressor levels and ecological effects

c) Risk Characterization -- the estimation of ecological risks, discussion of overall degree of confidence in the risk estimates, citation of evidence supporting risk estimates, and interpretation of the adversity of ecological risks

In addition, both the health and ecological risk assessment paradigms suggest to risk assessors that in order to write an overall risk characterization, each risk assessment section needs to have its own individual characterization. For human health risk, separate characterizations accompany the hazard identification, dose-response assessment and exposure assessment sections. For ecological risk, separate characterizations accompany the analysis plan, the stressor-response profile and the exposure profile. These separate, component characterizations carry forward the key findings, assumptions, strengths and limitations, etc. for each section and provide a fundamental set of information used in an integrative analysis that must be conveyed in the final overall risk characterization.

The overall risk characterization lets the manager, and others, know why EPA assessed the risk the way it did in terms of the available data and its analysis, uncertainties, alternative analyses, and the choices made. A good risk characterization will restate the scope of the assessment, express results clearly, articulate major assumptions and uncertainties, identify reasonable alternative interpretations, and separate scientific conclusions from policy judgments. The Risk Characterization Policy calls for the explanation of the choices made to be highly visible.

Importantly, remember that risk characterization is not just about science. It makes clear that science doesn't tell us certain things and that science policy choices must be made. It explains why the risk assessment result is the way it is given all the choices made during the course of the risk assessment process. And when others have also assessed the agent in a biologically plausible fashion, even if their assessment does not agree with EPA's assessment, it makes clear that EPA has assessed the agent this way but that others have assessed it differently.

Risk characterization is not only about science -- it is also about making clear that science doesn't tell us certain things and that policy choices must be made.

1.2.2 Are Risk Characterizations Written As Part of Ecological Risk Assessments Different from Those Written As Part of Human Health Risk Assessments?

In practice, the goals of ecological health and human health risk assessments are essentially the same. While there are some differences in the specific activities between the two

types of assessment (see specific appropriate EPA published guidelines), they generally approach an overall risk assessment and its associated risk characterization similarly.

a) Human health assessment adopts the problem formulation stage concept from ecological risk assessment and incorporates it into planning and scoping activities. Note that planning and scoping is not a specifically named step in the original 1983 NAS paradigm. However, planning and scoping are increasingly incorporated into the front end of human health risk assessment (e.g., see NRC, 1996; USEPA, 1997). Ecological risk assessment already incorporates a planning phase as well at the front end of its assessment process (USEPA, 1998). Ultimately, the efforts of these activities produce, in both types of assessments, a conceptual model that identifies the receptor issues/contaminants of concern and the potential exposure pathways for the assessment to concentrate upon. Chapter 2 provides more detail of the planning and scoping activities.

b) The analysis phase, where both exposure assessment and effects assessment or dose response analyses are conducted under ecological risk assessment, is similar to the dose response and exposure assessments conducted under human health risk assessment. While human health risk assessments focus on the risks to individuals and populations/subpopulations, ecological risk assessments may focus on individuals (for rare and endangered species), populations, communities, or ecosystems, depending on decisions made in the planning and scoping/problem formulation activities. The many risk assessment guidelines issued by the EPA provide much detail into the analyses needed in the assessment (references for these guidelines are found in Appendix F after the Handbook references).

c) Risk characterization is an integral part of the ecological risk assessment framework and is the final step in the human health risk assessment paradigm. For example, in ecological risk assessment, it is routine under risk characterization to address the ecological significance of the risks by asking the question “So what?” That is, if this risk exists as estimated, will it make a difference or be observed above the other dynamic factors operating in the environment? Similarly, the significance of human health risks relative to other similar hazards and activities is considered in its risk characterization. Chapter 3 provides more detail of the elements of a risk characterization.

1.2.3 Are Risk Assessment and Risk Characterization the Same?

No, they're not the same. Risk assessment is a process comprised of several steps (see section 1.2.1 above for detail). Risk characterization is the culminating step of the risk assessment process. Risk characterization communicates the key findings and the strengths and weaknesses of the assessment through a conscious and deliberate transparent effort to bring all the **important** considerations about risk into an integrated analysis by being clear, consistent and reasonable. Remember though, unless you actually characterize the assessment, the risk assessment is not complete -- risk characterization is an integral component of every risk assessment. As an example, just giving the quantitative risk estimate ("the number") is not a risk characterization.

1.2.4 Are Risk Characterization and Risk Communication the Same?

Risk characterization is an integral part of a risk assessment that summarizes the key findings and the strengths and weaknesses for risk managers and others. While it provides information that may be used to inform the public, risk characterization is not synonymous with risk communication. Risk communication emphasizes the process of exchanging information and opinion with the public, including individuals, groups, and other institutions, about levels of health or environmental risks. Risk communication is used for such things as information and education, behavior change and protective action, disaster warnings and emergency information, joint problem solving and conflict resolution. While the final risk assessment documentation (including the risk characterization) can be used to communicate with the public, the risk communication process is probably better served by separate documentation designed for particular audiences (Chapter 4 discusses this further).

1.2.5 What is the Value of Risk Characterization in the Regulation Development Process?

The risk characterization section of risk assessments that support rulemaking actions is an important, fundamental step informing the policy setting process. Risk characterization plus peer review provide a mechanism to help the Agency achieve scientific credibility. The risk characterization criteria of TCCR are essential, because new rules, and the work products supporting them, must often withstand intense scrutiny by the general public and the stakeholders affected by EPA's decisions. Although no rule or regulation itself is subject to the Risk Characterization Policy, the risk assessments that help inform the rules and regulations are subject to the Policy, and they should include risk characterization prior to use in any rule.

1.2.6 What Role does Risk Characterization have in Regulatory Negotiations?

Regulatory negotiations are not risk assessments; however, to ensure final decisions are based on sound and credible science, any risk assessments used during the regulatory negotiation need to be properly characterized before the negotiation is completed.

1.2.7 Do Risk Characterizations Need Peer Review?

The principle underlying the Peer Review Policy is that all major scientific and/or technical work products used in Agency decision making will be peer reviewed. Any risk assessment can be a candidate for peer review. Use the criteria in the Peer Review Handbook to determine which assessments need to be peer reviewed (USEPA, 2000).

Peer review is critical to ensure the scientific soundness of a risk assessment.

The risk characterization is an intrinsic part of the risk assessment. Generally, the entire risk assessment, with its risk characterization section, is the candidate for peer review. In some instances, the risk characterization piece itself may be a candidate for peer review. In performance of the peer review, you need to make sure that the TCCR criteria (see section 1.3 below for detailed discussion) are addressed in addition to the validity and credibility of the risk assessment itself.

1.3 Risk Characterization Principles

The Risk Characterization Policy states that "A risk characterization should be prepared in a manner that is clear, transparent, reasonable, and consistent with other risk characterizations of similar scope prepared across programs in the Agency." Risk characterization is therefore judged by the extent to which it achieves the principles of **T**ransparency, **C**larity, **C**onsistency, and **R**easonableness (TCCR).

While the Policy calls for TCCR in the risk characterization, the principles of TCCR need to be fully applied throughout every aspect of the risk assessment process. By applying TCCR principles from the planning and scoping stages, through the actual risk assessment, and then to all the communication and documentation of the risk assessment, the whole process will benefit and help better ensure success of all assessment efforts and products (including the risk characterization!).

Criteria are needed to fully implement the TCCR principles and to evaluate success. Because risk characterization, as called for in the Policy, clarifies EPA's way of doing business, risk assessors need some criteria to know what is asked of them as they prepare risk characterizations, risk managers need some criteria to know what to look for as they read risk characterizations, and the public needs some criteria to help them judge EPA's success in characterizing risk.

The sections below describe the criteria for TCCR. Before launching each risk assessment, the criteria should be kept in mind to help ensure that the risk assessment is well-characterized. After the assessment is complete, the criteria can be used to measure how well the assessment was characterized.

1.3.1 What are Criteria for Transparency?

Transparency provides explicitness in the risk assessment process. It ensures that any reader understands all the steps, logic, key assumptions, limitations, and decisions in the risk assessment, and comprehends the supporting rationale that lead to the outcome. Transparency achieves full disclosure in terms of :

a) the assessment approach employed

b) the use of assumptions and their impact on the assessment

c) the use of extrapolations and their impact on the assessment

d) the use of models vs. measurements and their impact on the assessment

e) plausible alternatives and the choices made among those alternatives

f) the impacts of one choice vs. another on the assessment

g) significant data gaps and their implications for the assessment

h) the scientific conclusions identified separately from default assumptions and policy calls

i) the major risk conclusions and the assessor's confidence and uncertainties in them

j) the relative strength of each risk assessment component and its impact on the overall assessment (e.g., the case for the agent posing a hazard is strong, but the overall assessment of risk is weak because the case for exposure is weak)

> ***Transparency is the principal value from among the four TCCR values, because, when followed, it leads to clarity, consistency and reasonableness.***

In many cases this will be a qualitative discussion and/or an acknowledgment that the assessor doesn't know the impact on the assessment due to uncertainty. For example, if there are no measurements for a given input to a risk assessment and a model or assumption is used and there is little information on the accuracy of the particular model or assumption for the particular type of application, then you may not be able to say anything meaningful about the impact on the assessment of using a model, other than to acknowledge the uncertainty inherent in using this model or assumption. Similarly, a complex risk assessment may have many assumptions imbedded in the analysis (all of which should be disclosed). However, the only way to know the impact of alternative choices in the model might require running the model many different ways and this might not be possible given resources (dollars and time). However, to the extent feasible within the resources and time available you should address the points noted above.

1.3.2 What are Criteria for Clarity?

Clarity refers to the risk assessment product(s). Making the product clear makes the assessment free from obscurity and easy to understand by all readers inside and outside of the risk assessment process. Clarity is achieved by:

a) brevity

b) avoiding jargon

c) using plain language so it's understandable to EPA risk managers and the informed lay person

d) avoiding the use of technical terms and, if used, by defining those terms

e) describing any quantitative estimations of risk clearly

f) using understandable tables and graphics to present the technical data

g) using clear and appropriate equations to efficiently display mathematical relationships (complex equations should be footnoted or referred to in the technical risk assessment)

1.3.3 What are Criteria for Consistency?

Consistency provides a context for the reader and refers to the presentation of the material in the risk assessment. For example, are the conclusions of the risk assessment characterized in harmony with relevant policy, procedural guidance, and scientific rationales and if not, why the conclusions differ. Also, does the assessment follow precedent with other EPA actions or why not. However, consistency should not encourage blindly following the guidance for risk assessment and characterization at the expense of stifling innovation. Consistency is achieved by:

a) following statutory requirements and program precedents (e.g., guidance, guidelines, etc.)

b) following appropriate Agency-wide assessment guidelines

c) using Agency-wide information, where appropriate, from systems such as the Integrated Risk Information System (IRIS)

d) putting the risk assessment in context with other similar risk assessments

1) how does it compare to other EPA assessments of similar agents or sites

2) how does it compare to others done by the scientific and regulatory community (e.g., other federal and state agencies, by other countries and/or by various interest groups; note: a reasonable search for similar assessments is expected)

i) how do the conclusions drawn by others differ from EPA's assessment

ii) what are the strengths and limitations compared to EPA's assessment

e) defining and explaining the purpose of the risk assessment (e.g. regulatory purpose, or policy analysis, or priority setting, etc.)

f) defining the level of effort (e.g. quick screen, extensive characterization) put into the assessment and the reason(s) why this level of effort was selected

g) following established Agency peer review procedures

1.3.4 What are Criteria for Reasonableness?

Reasonableness refers to the findings of the risk assessment in the context of the state-of-the science, the default assumptions and the science policy choices made in the risk assessment. It demonstrates that the risk assessment process followed an acceptable, overt logic path and retained common sense in applying relevant guidance. The assessment is based on sound judgment. Reasonableness is achieved when:

a) the risk characterization is determined to be sound by the scientific community, EPA risk managers, and the lay public, because the components of the risk characterization are well integrated into an overall conclusion of risk which is complete, informative, well balanced and useful for decision making

b) the characterization is based on the best available scientific information

c) the policy judgments required to carry out the risk analyses use common sense given the statutory requirements and Agency guidance

d) the assessment uses generally accepted scientific knowledge

e) appropriate plausible alternative estimates of risk under various candidate risk management alternatives are identified and explained

1.4 Overview Presentation of TCCR Principles

The following table presents an encapsulated overarching presentation of the TCCR principles and their criteria for a good risk characterization. It is meant to serve as a stand alone summary one-page guide for the use of TCCR throughout the risk assessment process.

Principle	Definition	Criteria for a Good Risk Characterization
Transparency	Explicitness in the risk assessment process.	✓ Describe assessment approach, assumptions, extrapolations and use of models ✓ Describe plausible alternative assumptions ✓ Identify data gaps ✓ Distinguish science from policy ✓ Describe uncertainty ✓ Describe relative strength of assessment
Clarity	The assessment itself is free from obscure language and is easy to understand.	✓ Employ brevity ✓ Use plain English ✓ Avoid technical terms ✓ Use simple tables, graphics, and equations
Consistency	The conclusions of the risk assessment are characterized in harmony with other EPA actions.	✓ Follow statutes ✓ Follow Agency guidance ✓ Use Agency information systems ✓ Place assessment in context with similar risks ✓ Define level of effort ✓ Use review by peers
Reasonableness	The risk assessment is based on sound judgment.	✓ Use review by peers ✓ Use best available scientific information ✓ Use good judgment ✓ Use plausible alternatives

1.5 The Roles of People and Organizations in Risk Characterization

1.5.1 Who is Ultimately Accountable for Risk Characterization?

Under the March 21, 1995 Risk Characterization Policy, the Administrator designated the Assistant Administrators, Associate Administrators, Regional Administrators (AAs and RAs), the General Counsel, and the Inspector General to be accountable for implementing the Policy in their respective organizations. In her memo to Senior Agency Management (Appendix A), the Administrator noted that:

> "These core values of transparency, clarity, consistency, and reasonableness need to guide each of us in our day-to-day work; from the toxicologist reviewing the individual cancer study, to the exposure and risk assessors, to the risk manager, and through to the ultimate decision maker. I recognize that issuing this memo will not by itself result in any change. You need to believe in the importance of this change and convey your beliefs to your managers and staff through your words and actions in order for the change to occur. You also need to play an integral role in developing the implementing policies and procedures for your programs."

While the above persons are ultimately accountable for ensuring health and ecological risk assessments from their organizations have proper risk characterizations, it is recognized much of the responsibility to ensure that the risk assessments include risk characterizations that are done well according to the principles of TCCR is delegated to their Risk Managers.

1.5.2 Who Are the Agency Staff Involved in Risk Characterization?

The principal Agency staff are risk assessors and risk managers. Risk assessors are the scientific and technical staff who actually perform the various components of the risk assessment.

1.5.3 What Are My Responsibilities as a Risk Assessor?

People who perform the risk assessment, in whole or in part, are the risk assessors. Risk assessors rely heavily on the risk assessment guidelines to help guide the risk assessment and address science policy issues and scientific uncertainties specific to the endpoint in each guideline. You may fall into either of two major groupings of risk assessors, or both:

a) Risk assessors that develop chemical- or stressor-specific risk assessments

b) Risk assessors that generate site- or medium-specific risk assessments – these assessors usually rely on existing databases and site- or media-specific exposure information (e.g., IRIS, HEAST, OPP database, Exposure Factors Handbook)

Regardless of which group you are in, your major responsibility as a risk assessor is to communicate your key risk findings and conclusions and your confidence in them in the risk characterization section of your assessment. Your basic job is to write the risk assessment with the technical risk characterization (see section 4.2.1).

Your specific responsibilities are to:

a) Explain what is the risk, what individuals, populations or systems are affected and by what route of exposure

b) Describe your level of comfort with the conclusions and what degree of certainty you place in them

1) Summarize and identify the key pieces of information critical to your evaluation

2) Let your manager know whether the key data used for the assessment are considered experimental, state-of-the art or generally accepted scientific knowledge

c) Describe quantitative risk estimates in plain English; the use of tables and graphics may be helpful as a supplement

d) Describe the uncertainties inherent in the risk assessment and the default positions used to address these uncertainties or gaps in the assessment

e) Refer the reader to an Agency risk assessment guideline or other easily obtainable reference that explains terminology (e.g., how a RfC was developed)

f) Put this risk assessment into a context with other similar risks that are available to you and describe how the risk estimated for this stressor, agent or site compares to others regulated by EPA

g) Describe how the strengths and weaknesses of EPA's assessment compare with other assessments prepared by EPA in the past

h) Describe the rationale and bases for the conclusions drawn by those outside EPA about this agent, stressor or site

   1) If their conclusions differ from yours, let the manager know whether theirs is a reasonable alternative

   2) Can their conclusions reasonably be derived from the data set

   3) Inform the manager of the strengths and weaknesses of their evaluations compared to yours

i) If you have developed specific assessments for one or more risk management alternatives, let the risk manager know what changes in risk would occur under these various candidate risk management alternatives

j) Highlight areas in the assessment which might be overlooked or misinterpreted by the risk manager

k) Keep the decision maker informed of the status of your risk assessment and risk characterization

l) Organize, conduct, and complete the risk characterization following Agency procedures

m) Archive the risk characterization record in a manner consistent with your organization's archiving procedures

1.5.4 What Are My Responsibilities as a Risk Manager?

Risk managers are generally the decision makers in their organization. The AA/RA is the ultimate decision maker for his/her organization and is accountable for both the risk characterization process and products in his/her office. The AA/RA may designate Office Directors, Division Directors, and/or Branch Chiefs (or other appropriate level line-managers) as the front-line decision makers. Generally, the decision makers commit the resources needed to ensure a proper risk assessment which includes a complete risk characterization.

As a risk manager, you are responsible for ensuring that risk assessments, containing risk characterizations, are properly performed and documented. You are also responsible for ensuring

that the key information from each risk characterization is honestly and clearly elevated up the management chain and communicated to senior management. As a decision maker, you integrate the risk characterization with other considerations specified in applicable statutes, Agency and office policies, executive orders, and other factors (e.g., see Chapter 5) to make and justify regulatory decisions.

Your specific responsibilities are:

a) Promote a culture supportive of preparing risk characterizations and ensure that all risk assessment work products produced by or submitted to your organization are well characterized

b) Provide advice, guidance, and support for the preparation, conduct, and completion of a full risk characterization for each assessment

c) Play a major role in determining the scope of the risk assessment

d) Ensure that sufficient funds are designated in the office's budget request to conduct a risk characterization for each risk assessment

e) Establish a realistic risk assessment schedule that includes risk characterization

f) Designate the stage(s) of product development where risk characterization is appropriate

g) Ensure that the characterizations prepared by individual risk assessors for their portion of each risk assessment document are integrated into a complete risk characterization for each risk assessment

h) Provide proper risk assessment training for your staff including how to write risk assessments and their characterizations

i) Establish systems to maintain records of the risk assessments, including risk characterizations, prepared by risk assessors under your supervision

j) Ensure that the key points from the risk characterization are carried forward in all deliberations or considerations for decision making

1.5.5 What Does the Risk Characterization Policy Tell Risk Assessors?

The policy tells risk assessors to include the following in the risk characterization:

a) Carry forward the key information from hazard identification, dose-response, and exposure assessment, using a combination of qualitative information, quantitative information, and information about uncertainties

Risk characterization communicates the key strengths and weaknesses of the assessment through a conscious and deliberate effort to bring all the important considerations about risk into an integrated picture.

b) Discuss uncertainty and variability appropriate for the level of analysis

c) Present risk conclusions and information regarding the strengths and limitations of the assessment at the level appropriate for the risk assessment (e.g., if it is a screening assessment the risk characterization portion of the risk assessment should be brief)

1.5.6 How Will Risk Characterization Help the Risk Assessor?

Risk characterization makes the whole risk assessment story clearer and easier to communicate. If you properly characterize risk, your risk assessment is easier to explain, justify, and defend.

1.5.7 How Will Risk Characterization Help the Risk Manager?

Risk characterization allows you to understand and better communicate risk assessment findings. You can better convey information up the management decision-making chain and to the public. Transparency is a powerful tool. You can use it to ensure clarity, consistency and reasonableness to achieve a better-informed decision.

Risk managers have made the following comments about risk characterization:

a) Being transparent helps me make better-informed decisions

   1) It brings out the usually unseen parts of the assessment

2) When I require transparency, I can incorporate clarity, consistency and reasonableness to achieve a better-informed decision

3) Helps me understand the scientific basis of my decisions

4) Helps me build trust and credibility with staff, public and stakeholders

b) Communication helps and it has two parts

1) When I ask questions, getting to TCCR is facilitated

2) I need to ask early and to check progress often

1.5.8 Which Office/Region or Other Agency is Responsible for Writing the Risk Characterization?

The organization preparing the risk assessment is normally responsible for preparing the risk characterization. If more than one Agency office or region or other agencies are involved, each is responsible for characterizing that component of the assessment they prepared. The responsibility for preparing the overall risk characterization is usually accepted by the office making the decision, but this can be negotiated.

1.5.9 What is the Responsibility of Organizations that Submit Risk Assessments to EPA?

Just as the Agency is expected to follow its own guidance for characterizing risk in every risk assessment, the Agency expects that any risk assessment done by any organization for EPA consideration and possible use will include a proper risk characterization that is transparent, clear, consistent and reasonable and addresses the risk characterization elements. The Agency reserves the right to determine the acceptability of the submitted risk assessment and its characterization and will evaluate each submission in line with the guidance in this Handbook.

If the submitting party has questions about any aspect of the risk assessment, it may want to contact the agency office or region that is associated with and ultimate recipient of the assessment. Care should be taken to make it clear that while the Agency is glad to comment on questions presented about the assessment and risk characterization, it will not provide any approval or commitments prior to its evaluation of the actual final submission.

1.5.8 What is the Role of the Science Policy Council (SPC)?

The Science Policy Council (SPC) will consult with each Program Office and each Region as they implement risk characterization. The SPC will also periodically evaluate the Agency's experience with risk characterization and as necessary will provide supplemental guidance or when appropriate, revise this Handbook. The implementation of the Risk Characterization Policy is the responsibility of management within each Office or Region.

2. PREPARING FOR A RISK ASSESSMENT AND ITS RISK CHARACTERIZATION – PLANNING AND SCOPING

2.1 Overview

The risk characterization is the summarizing step of the risk assessment. However, the participants in the colloquia and roundtables noted that the risk characterization principles of TCCR and the elements of risk characterization (described in Chapter 3) offer powerful tools to help plan and scope a risk assessment before it is begun. Therefore, these principles should be considered by risk assessors, risk managers and others as they begin each new assessment. Planning and scoping is an important first step to ensure that each risk assessment has a clear purpose, has a defined scope, and is well thought out. These provide a sound foundation for judging the success of the risk assessment and for an effective risk characterization.

If you begin the overall risk assessment process with planning and scoping, you set a sound foundation for a good risk characterization at its end.

2.2 Planning and Scoping

Based on EPA's experience with the four-step NAS risk assessment paradigm (NAS, 1983), it has become clear that the additional step of planning and scoping is needed at the front end of the risk assessment process. This will help ensure that a risk assessment is well done and is well characterized. In 1997, the Agency issued preliminary planning and scoping guidance in the context of cumulative risk (USEPA, 1997). A more developed Planning and Scoping Guide is currently being written under the auspices of the Agency's Science Policy Council. This Guide should be referred to when published for greater detail on planning and scoping, particularly as to cumulative risk assessment and stakeholder involvement.

Planning and scoping can be viewed as a lens that defines the purpose and scope of a risk assessment and focuses the issues involved in performing the assessment. The risk characterization portion of the risk assessment, in turn, is a second lens that focuses the conclusions of the risk assessment into a coherent picture for applying and communicating the assessment. At the end of the risk assessment, a comparison of the risk assessment, including the risk characterization, with the goals and objectives defined during planning and scoping can provide a useful measure of success.

2.2.1 What Should You Discuss During Planning and Scoping?

Planning and scoping provides the opportunity for the risk manager(s), the risk assessor(s), and other members of the "team" to define what is expected to be covered in the risk assessment and to explain the purposes for which the risk assessment information will be used. During the planning and scoping phase of the risk assessment process risk assessors and risk managers should engage in a dialog to identify:

a) Motivating need for the risk assessment (regulatory requirements? public concern? scientific findings? other factors?)

b) Management goals, issues, and policies needing to be addressed

c) Context of the risk

d) Scope and coverage of the effort

e) Current knowledge

f) What and where are the available data

g) An agreement about how to conduct the assessment including identifying:

   1) Resources available to do the assessment

   2) Participants in the process

   3) Plans for coordinating across offices, with other agencies and with stakeholders

   4) Schedule (e.g., milestones) and time frame

h) Plans for how the results will be communicated to senior managers and to the public

i) Information needs/data for other members of the “team” to conduct their analyses (e.g., economic, social, or legal analyses)

Another discussion during the planning and scoping process concerns the identification of key data gaps and thoughts about how to fill the information needs. For example, can you fill the information needs in the near-term using existing data, in the mid-term by conducting tests with currently available test methods to provide data on the agent(s) of interest, and over the long-term to develop better, more realistic understandings of exposure and effects and to construct more realistic test methods to evaluate agents of concern? In keeping with TCCR, care must be taken not to set the risk assessment up for failure by delaying environmental decisions until more research is done. Planning and scoping discussions about filling information/data gaps should include:

a) Do you have enough data to perform the risk assessment despite having certain information gaps

b) When will the results be available

c) Will the results likely make a real difference in the assessment

d) To what extent will a policy call have to be made when data are unavailable or are not certain

2.2.2 Should the Planning and Scoping Discussion Focus on What the Risk Assessment Results Should Be?

No! While Agency risk managers should meet often with their risk assessors and other team members to discuss the need for, and the context of, the risk assessment, the discussions should definitely not touch upon what the risk assessment result(s) should be. The purpose of these discussions is to ensure that the needs for the assessment are well understood by those conducting it, that the assessment is properly scoped, and that the results will be timely and useful for the intended purpose.

2.2.3 What are Possible Products Emerging from Planning and Scoping?

Products that can emerge from the planning and scoping process are the conceptual model with its associated narrative and the analysis plan. The conceptual model is a visual presentation relating sources and releases of possible contaminants or the level of ambient concentrations to exposure of people and ecosystems which result in potential adverse effects to human health or ecology. The narrative explains the rationale for the nature of the conceptual model developed.

The analysis plan is the final stage of planning and scoping and is a bridge to the risk assessment. The analysis plan is the implementation strategy for performing the risk assessment and addressing the Agency's needs. It documents the agreements made during the planning and scoping process and provides details on how the risk assessment will proceed. This provides transparency to the whole process. In addition, the analysis plan provides measures against which the final risk assessment and its risk characterization can be evaluated. As the risk assessment proceeds, the analysis plan may need to be revisited and refined to ensure that the risk assessment still meets the Agency's needs.

In general, conceptual models and analysis plans are candidates for peer review. Peer review early in the risk assessment process can provide additional insights, corrections to assumptions, and directions on proper ways to proceed during the risk assessment (see Section 1.2.7). These are valuable additions to the Agency's way of conducting business.

2.2.4 What Are the Benefits of Planning and Scoping?

The planning and scoping process helps risk assessors understand how their risk assessment and its characterization fit into the overall environmental decision-making process. Preliminary information on the various inputs to decision-making, the possible roles and participation of stakeholders, and how the analyses will be peer reviewed are considered at the planning and scoping stage. Management concerns about funding, human resources, timing etc. are also discussed. This is important information to the risk assessor.

Planning and scoping promotes:

a) Initial planning to save time and resources, and buy-in by stakeholders or interested parties by setting realistic expectations

b) Better-informed decisions, and the prospect of less controversy (e.g., fewer court cases, criticism)

c) Participation by those from many disciplines (e.g., economists, lawyers) to help in the process thereby ensuring that each risk assessment and characterization is useful for the intended audience(s), and is of the scope and degree of complexity needed to inform the decision at hand in conjunction with other analyses, for instance, economics.

2.2.5 Who Does Planning and Scoping?

The planning and scoping process involves relevant risk managers, risk assessors and other members of the "team" working on the decision that needs to be made. The other members include the economists, lawyers, engineers, policy makers, etc. working on the issue at hand. To ensure that risk assessment meets the Agency's needs, and that those who will use the results are fully informed, the communication within the team begun during the planning and scoping phase should continue throughout the risk assessment process until the final risk characterization is communicated to the decision maker(s) and beyond in certain cases (e.g. litigation support).

Stakeholders (interested and affected parties) may participate during the planning and scoping process depending upon the nature of the problem, their interest, and ability to contribute. Affected parties can share their points of view about the risk and how it should be managed. Their input is particularly helpful in determining what should be included in the assessment, how they might be affected or exposed to the risk, and what additional data or exposure scenarios should be developed. Early in the planning and scoping of the risk assessment, decisions need to be made about who the stakeholders are and how they will participate.

2.2.6 When Does the Risk Assessor/Risk Manager Dialog End?

Risk assessors work with risk managers and others as a team. Ongoing dialog before and during the assessment is essential for its successful completion. Generally, once the risk management decision is made, the ongoing dialog usually ends. However, since emphasis on evaluating the effectiveness of the risk management action and decision has become part of the Agency's way of doing business (due to the Government Performance Results Act (GPRA)), there will probably be an occasional need for the risk assessors and risk managers to discuss the assessment after the risk management decision is made.

2.3 Typology for Risk Characterization

As the Policy states, EPA conducts many types of risk assessments. Assessments involve various levels of complexity to support the wide range of decisions that have an impact on human and environmental health. These include screening-level assessments of new chemicals, in-depth assessments of pollutants such as dioxin and environmental tobacco smoke, and site-specific assessments for hazardous waste sites. An iterative approach to risk assessment, beginning with screening techniques, may be used to determine if a more comprehensive assessment is necessary. The degree to which confidence and uncertainty are addressed in a risk characterization depends largely on the scope of the assessment. In general, the scope of the risk

characterization should reflect the length, depth, and breadth of the corresponding risk assessment. When special circumstances (e.g., lack of data, extremely complex situations, resource limitations, statutory deadlines) preclude a full assessment, such circumstances need to be explained and their impact on the risk assessment discussed in the risk characterization.

During the planning and scoping stages of the risk assessment process, discussions about the level of effort and complexity of detail take place in regards to the upcoming risk assessment. These discussions may be revisited once the assessment is underway. A decision typology adapted from the NRC (NRC, 1996) is provided below to help you think about the possible information needs for decision making and the effort needed to develop such information. While this typology doesn't cover all possible circumstances, it provides an example range of effort needed for risk assessments (including risk characterizations).

This typology, derived from the NRC (1996), should be borne in mind as the risk assessment is planned, scoped and conducted to ensure that the risk characterization section of the assessment is of the proper level of detail for the task at hand.

a) ***Unique, wide-impact decisions and risk characterizations.*** The risk characterization informs single-time decisions that uniquely impact the health of large numbers of people or large portions of the environment, sometimes over long periods of time. Typically, they are controversial, with disparate perspectives on the nature and extent of the risk and a spectrum of affected parties and visible, interested stakeholders.

   Those planning the risk assessment process will no doubt recognize and have the support for extensive risk analyses with broad participation. But the nature of the process will be particularly important in achieving a risk characterization that will be useful in the decision-making process.

b) ***Routine, narrow-impact decisions and risk characterizations.*** Risk characterizations of this type will be very similar to previous ones that have been performed. Typically, the impact under review will involve a small geographical area and few people. Examples of risk characterizations of this type are the thousands of screening level site-specific risk characterizations performed annually to support air permit decisions for small facilities. Other examples are the screening level chemical use-specific characterizations that may be developed in evaluating circumstances for chemical manufacture as with the premanufacturing notice program for new chemicals under the Toxic Substances Control Act (TSCA).

Significant unresolved issues may underlie individual risk characterizations of this type. However, it will be neither practical nor desirable to debate the assumptions and develop multiple descriptions for each risk characterization. The most reasonable course is to make the process and characterization development routine, but provide the opportunity for appeal. Also, there should be periodic review of the routine procedures.

c) ***Repeated, wide-impact decisions and risk characterizations.*** Risk characterizations of this type have wide impact; that is, they support decisions that can have an impact on large numbers of people or large geographical areas. However, the characterizations developed are similar in structure to ones done previously with respect to issues discussed and supporting risk assessments. Also, in planning and scoping the assessment process, the issues are likely to be similar to those previously raised.

Therefore, some aspects can be made routine, although certain other aspects may need special attention so that they meet the unique needs of the particular decision at hand. Also, questions should be raised at the start to attempt to uncover issues important to the decision that would not be anticipated on the basis of other similar risk characterization exercises. An example of this type of characterization would be one performed in support of the siting of a large waste incineration facility.

d) ***Generic hazard and dose-response decisions and risk characterizations.*** Risk characterizations of this type are one step removed from the characterization of a particular chemical use or site-specific risk. In fact, they typically support the routine risk characterizations described above. Since they fall outside specific decisions at hand, it is sometimes difficult to appreciate the full range of issues. Indeed, it may be a challenge to construct a risk assessment or characterization development and review process with adequate participation, absent a particular decision context.

3. ELEMENTS OF A RISK CHARACTERIZATION

3.1 Overview

Risk characterization does not stand alone. It is one of the four steps in risk assessment. It is very important that risk characterization be done well because it is the final component of the risk assessment process. There is only a single technical characterization of risk as a final product of the assessment (see section 4.2.1). This technical characterization must be written with enough detailed technical information so that another expert (e.g., other risk assessors, peer reviewers) can reasonably reconstruct what was done in the assessment, including being able to identify the assumptions made during the assessment. Since the risk characterization is a part of the risk assessment itself, keep in mind that the goal of the risk characterization is not to repeat the entire assessment, just to identify the key elements from the risk assessment that really make a difference in its outcome.

There is only a single technical characterization of risk as a final product of the risk assessment.

The actual elements that go into an assessment are addressed in the many risk assessment guidelines and program-specific guidance documents that are issued by the EPA. You need to refer to the guidelines while conducting a risk assessment (see reference list at end of this Handbook for these guidelines). Those materials that guide you through the risk assessment will not be reiterated here. This Handbook provides guidance for the risk characterization part of the risk assessment.

This chapter presents many of the elements you need to consider when drafting the risk characterization part of your assessment. You should not use a checklist approach here. Instead, you should consider the elements presented below while writing your risk characterization. Whether every element is actually written into the characterization or not is dependent upon the purpose of the risk assessment and the detail necessary to adequately characterize it.

3.2 Elements of a Risk Characterization

By the time you have completed your assessment, you should have identified the universe of policy choices, management decisions, and uncertainties, as well as the conclusions of your risk assessment. The point of risk characterization is not to repeat the entire risk assessment, but rather to describe the **key** findings and other elements (i.e., not all the issues and conclusions, only the key information) from each step of the human health or ecological assessment paradigm. Because key findings differ for each assessment, it is not possible to define exactly what they are

generically. Professional judgment is necessary to define them. You will want to alert the risk manager to the major elements that affect the characterization:

a) Key information (section 3.2.2)

b) Context (section 3.2.3)

c) Sensitive Subpopulations (section 3.2.4)

d) Scientific Assumptions (section 3.2.5)

e) Policy Choices (section 3.2.6)

f) Variability (section 3.2.7)

g) Uncertainty (section 3.2.8)

h) Bias and Perspective (section 3.2.9)

i) Strengths and Weaknesses (section 3.2.10)

j) Key Conclusions (section 3.2.11)

k) Alternatives Considered (section 3.2.12)

l) Research Needs (section 3.2.13)

3.2.1 Can a "Bright Line" or Number be the Risk Characterization?

No! Whatever the form the risk characterization takes, don't just give the "number." The goal is to give an understandable, rich description of the findings and the strengths and weaknesses of the assessment, i.e., avoid the single "bright line" presentation. Every risk characterization has a fundamental, irreducible set of information consisting of the **key** findings that must be conveyed to every audience to adequately characterize the risk; again, it is more than just a number.

3.2.2 What Key Information Needs to Be Identified During the Risk Assessment Process to Prepare for Risk Characterization?

When you prepare a risk characterization, you need to think about what is the information to present in the risk characterization. The following provides some considerations to help you capture the key information from the risk assessment to carry forward into the risk characterization. For each stage of the assessment for human health or ecological risks, the assessor identifies:

a) The studies available and how robust they are (e.g., have the findings been repeated in an independent lab)

b) The major risk estimates calculated, the assumptions and the extrapolations made during the estimated risk calculation, and the residual uncertainties and their impact on the range of plausible risk estimates. Your description of the risk estimate should indicate what you are assessing (e.g., individual, population, ecosystem) and include such things as the high end and central tendency estimates.

c) Use of defaults, policy choices and any risk management decisions made (e.g., refer the reader to an Agency risk assessment guidance, guideline, or other easily obtainable reference source that explains the meaning of terminology)

d) Whether the key data used for the assessment are considered experimental, state-of-the art or generally accepted scientific knowledge

e) The meaning of quantitative data in an easily understandable form -- the use of tables and graphics may be helpful

f) Variability (see section 3.2.7)

3.2.3 How Do I Put the Risks Estimated in this Assessment into a Context with Other Similar Risks?

It is important for the risk manager to know how the estimated risk from this agent or site compares to similar risks. Two types of comparisons should be considered. The first is to compare this risk assessment with

Discussions about how the likely risk from this stressor, agent or site compares to others regulated by EPA can provide a valuable tool to risk managers.

previous Agency decisions to provide a feel for the comfort level, weight of evidence, and likely problems the Agency will have with this assessment when comparing it to past Agency assessments. The second is to provide a sense of how generally the assessment is accepted by the scientific and regulatory community at large by comparing the results of EPA's assessment on this agent or site with available assessments made on the same agent or site by other federal and state agencies, by other countries and/or by various interest groups.

a) Comparisons to Agency assessments

   1) Let the risk manager know what other risk assessments have been performed on this agent or site or similar agents and sites

   2) Describe how the strengths and weaknesses of EPA's assessment compare with other assessments prepared by EPA in the past

b) Comparisons to assessments done by others

   1) Describe the rationale and bases for the conclusions drawn by others about this agent if they differ from EPA's assessment

   2) If their assessment differs from EPA's, is it a reasonable alternative (i.e., can their conclusions reasonably be derived from the data set)

   3) What are the strengths and weaknesses of their evaluations compared to EPA's assessment

3.2.4 How Do I Address Sensitive Populations, Ecosystems and Species?

In its risk assessments and risk characterizations, the EPA attempts to identify the universe of people that may be affected, including sensitive populations (e.g., children, ethnic groups, gender, age, nutritional status, other genetic predisposition), ecosystems or ecological entities (e.g., endangered species), and those that are highly exposed (e.g., human, wildlife, etc.). In the planning and scoping phase of the risk assessment process, the potential for exposures or for unique adverse effects to sensitive populations should be noted. Any sensitive populations that are identified should be evaluated in the risk assessment, and the assessment should contain an appropriate characterization. It may not be necessary or possible to do a quantitative risk assessment on each one. For instance, where there are many sensitive population groups for a given pollutant, it may be sufficient to estimate risks for the most sensitive group and as long as they are protected, other groups may be protected adequately.

While all sensitive populations need to be considered, Executive Order 13045 entitled "Protection of Children from Environmental Health Risks and Safety Risks" (April, 1997), and the Administrator's "Policy on Evaluating Health Risks to Children" (October, 1995), specifically require that EPA risk assessments, risk characterizations, and environmental and public health standards characterize health risks to infants and children as appropriate.

The following points are illustrative of the information that can be valuable in the assessment and characterization of children's risk. As risk assessors conduct their risk assessment, they should consider these factors about children's risks in their risk characterization. The first two points to consider should be part of the fundamental, irreducible set of information carried forward in the risk characterization:

a) Have the potential hazards to children been adequately characterized?

b) Have the exposures to children been adequately characterized?

In addition, the Agency has issued specific guidance for rule writers about how to address children's risk pursuant to Executive Order 13045. This is found in the "EPA Rule Writer's Guide to Executive Order 13045" issued as interim final guidance in April 1998 (USEPA, 1998).

3.2.5 What are Scientific Assumptions and How Do I Address Them?

Because we only have a limited amount of information from laboratory, human, and field studies, it is necessary to predict the effects that will occur after exposures to environmental pollutants. For some pollutants data are available from certain stages of development but not others. Or perhaps the study was conducted in one sex only or in a certain ethnic population or one whose diet is much different from that in the U.S. In such cases, it is necessary to describe the variation and unpredictability of responses to toxicant exposure at different developmental stages, to the other sex or another population, as well as other complexities (e.g., the possibility of delayed response).

At EPA, various risk assessment guidelines have been written to ensure a scientifically defensible and consistent approach to risk assessment. When you write the risk characterization portion of your assessment, indicate whether or not you followed the guidelines and describe the key assumptions you made during your assessment and the impact they have on the assessment outcome. For example, if the endpoint of concern is ovarian cancer, it makes no difference and is not worth noting that males were not studied for ovarian cancer. However, in other cases, for example, if the cancer risk from carcinogenicity from drinking water contaminated by arsenic is being considered, the effect of diet on the disease outcome should be stressed.

3.2.6 What Are Policy Choices and How Do I Address Them?

In years past, different EPA offices sometimes had different policies about how to assess risk (e.g., different uncertainty factors or different levels of regulatory concern). While the development of the various risk assessment guidelines and the establishment of the Science Policy Council have helped to eliminate such discrepancies, possibilities for policy choices affecting risk assessment outcomes still exist in EPA (i.e., different laws and their implementing regulations may still dictate divergent policies). Also, there may be important differences between EPA's risk assessment policy choices and those of other agencies. To the extent you are aware of such information be sure to describe it in the risk characterization portion of your assessment and to let your manager know of the impact the alternative policy choices have on the outcome of your assessment.

3.2.7 How Do I Address Variability?

The risk assessor should strive to distinguish between variability and uncertainty to the extent possible (see 3.2.8 for a discussion of uncertainty). Variability arises from true heterogeneity in characteristics such as dose-response differences within a population, or differences in contaminant levels in the environment. The values of some variables used in an assessment change with time and space, or across the population whose exposure is being estimated. Assessments should address the resulting variability in doses received by members of the target population. Individual exposure, dose, and risk can vary widely in a large population. Central tendency and high end individual risk descriptors capture the variability in exposure, lifestyles, and other factors that lead to a distribution of risk across a population (e.g., see Guidelines for Exposure Assessment; referenced in Appendix F).

3.2.8 How Do I Address Uncertainty?

Uncertainty represents lack of knowledge about factors such as adverse effects or contaminant levels which may be reduced with additional study. Generally, risk assessments carry several categories of uncertainty, and each merits consideration. Measurement uncertainty refers to the usual error that accompanies scientific measurements -- standard statistical techniques can often be used to express measurement uncertainty. An amount of uncertainty is often inherent in environmental sampling, and assessments should address these uncertainties. There are likewise uncertainties associated with the use of scientific models, e.g.,dose-response models, models of environmental fate and transport.

Evaluation of model uncertainty considers the scientific basis for the model and available empirical validation. A different kind of uncertainty stems from data gaps; that is, estimates or

assumptions used in the assessment. Often, the data gap is broad, such as the absence of information on the effects of exposure to a chemical on humans or on the biological mechanism of action of an agent. The risk assessor should include a statement of confidence that reflects the degree to which the risk assessor believes that the estimates or assumptions adequately fill the data gap. For some common and important data gaps, Agency or program-specific risk assessment guidance provides default assumptions or values. Risk assessors should carefully consider all available data before deciding to rely on default assumptions. If defaults are used, the risk assessment should reference the Agency guidance that explains the default assumptions or values.

While it is generally preferred that quantitative uncertainty analyses are used in each risk characterization, there is no single recognized guidance that currently exists on how to conduct an uncertainty analysis. Nonetheless, risk assessors should perform an uncertainty analysis. Even if the results are arrived at subjectively, they will still be of great value to a risk manager. The uncertainty analysis should, in theory, address all aspects of human health and ecological risk assessments, including hazard identification, dose-response assessment, and exposure assessment. Uncertainty analysis should not be restricted to discussions of precision and accuracy, but should include such issues as data gaps and models.

Identify those scientific uncertainties that if reduced (e.g., about whether or not we know if the agent causes cancer, about whether or not we know what happens at low doses, that we know the exposure only occurs in certain specific locations) or the policy choices and management decisions that if changed would make a real impact on the risk assessment.

3.2.9 How Do I Address Bias and Perspective?

There is an understood, inherent, EPA bias that in the light of uncertainty and default choices the Agency will decide in the direction of more public health protection than in the direction of less protection. However, it is not always clear where such bias enters into EPA risk assessments. To the extent it may make a difference in the outcome of your assessment, highlight the relevant areas so the impact will not be overlooked or misinterpreted by the risk manager.

3.2.10 How do I Address Strengths and Weaknesses?

Identify major imbalances among the components of the assessment. For example, the case for the stressor or agent posing a hazard may be strong, while the overall assessment of risk is weak because there are no data about whether there is exposure to the stressor or agent.

3.2.11 What Are the Major Conclusions to Carry Forward?

Each component of the risk assessment (e.g., hazard identification, exposure assessment, etc.) contains its own summary "mini-characterization." When integrated, these identify the fundamental, irreducible set of key points that must be communicated to characterize adequately the corresponding section of that risk assessment. Because every risk assessment has many uncertainties, and involves many assumptions, the challenge in characterizing risk for decision makers, whose time is limited and who are not risk experts, is to convey that small subset of **key** findings and strengths and limitations that really makes a difference in the assessment outcome.

The goal of Risk Characterization is not to repeat the entire assessment, just the key findings and conclusions.

a) Bring out those key strengths and weaknesses in plain English consistent with TCCR

b) Provide a brief bottom line statement about the risks, including your confidence in any estimate(s) of risk and in your conclusions

c) Help the reader clearly grasp what is known about the nature, likelihood and magnitude of any risk

The idea is to relay to the risk manager in frank and open terms the scope, strengths, and limitations of the assessment. An example of possible strengths of an assessment would be that the overall weight of evidence of the data indicates that the quality and quantity of data supporting the hazard and/or exposure is high. There might also be general consensus within the scientific community on certain points used to build the hazard/exposure case.

If you know of information that would yield changes in the risk estimates under various candidate risk management alternatives, let the manager know. For instance, if a feasibility study has been performed that evaluates the risk associated with different treatment technologies or remedial alternatives, discuss the range of possible outcomes and the implications of each.

It is important to remember that while you are conducting your risk assessment you need to think about what the key points are that you want to present in the risk characterization portion of the assessment.

3.2.12 How Do I Describe the Alternatives Considered?

As you prepare the risk characterization section of your risk assessment you should ask yourself what are the qualitative characteristics of the hazard (e.g., voluntary vs. involuntary, technological vs. natural, etc.)? You should also comment on findings, if any, from studies of risk perception that relate to this hazard or similar hazards and let the risk manager know:

a) What are the alternatives to this hazard? How do the hazards compare?

b) How does this risk compare to other risks?

1) How does this risk compare to other risks in this regulatory program, or other similar risks that the EPA has made decisions about?

2) Where appropriate, can this risk be compared with past Agency decisions, decisions by other federal or state agencies, or if appropriate, to common risks with which people may be familiar?

You should describe the limitations of making these comparisons, and comment on significant community concerns which influence public perception of risk, if known.

You should also comment on other risk assessments that have been done in similar situations (e.g., specific chemical, similar site) by EPA, other federal agencies, or other organizations. Are there significantly different conclusions that merit discussion? Is there other information that would be useful to the risk manager or the public in this situation that has not been described above?

3.2.13 How Do I Address Research Needs?

While many data needs and methodology gaps are identified when assessing risk, **only the key ones that really make a difference** in the risk assessment outcome are highlighted in the risk characterization portion of the risk assessment. A systematic capturing of such needs identified during risk characterization may provide an effective way to identify high priority scientific support needs and a mechanism to reduce the tension within EPA between the need for immediate technical support for today's regulations and the need to improve test methods and risk assessment models to more realistically estimate risk from environmental exposures.

3.3 Should Decisions be Delayed Until Research is Completed?

Unless the research need is so compelling as to its critical use in the risk assessment, a decision should not be delayed unduly to fulfill the need. Research is never certain and it often raises additional questions. The main benefit of risk characterization is that it provides context for available information for use in decision making and for strengthening the scientific underpinnings of the Agency's decisions.

4. RISK CHARACTERIZATION-RELATED PRODUCTS

4.1 Overview

The portion of the risk assessment referred to as risk characterization is the final summarizing product of the risk assessment process (elements discussed in Chapter 3). This is referred to as the "technical" risk characterization. Once this is written, it can be used as the basis for subsequent communication instruments or **products** for audiences beyond the technical users of the characterization. The communication of the risk characterization will take different written and oral forms to meet the needs of the intended audiences (e.g., risk managers, the public). Thus, the communication of risk requires different **products** for different audiences at different times. In other words, it is probably not realistic to expect one product to serve diverse audiences equally.

The level of information contained in each product will vary according to the detail of the risk assessment which is being characterized by this product. In addition, it will often vary in format or detail in order to effectively communicate with the intended audience. Use good judgment and common sense.

Remember, risk characterization is not synonymous with risk communication. While the final risk assessment document (including the technical risk characterization) is available to all audiences, the risk communication process may be better served by separate products designed for particular audiences. This chapter deals with these separate "risk characterization" products and their audiences.

4.2 Products of Risk Characterization

Because there is more than one audience for each assessment, there will probably be more than one risk characterization product written or spoken about the risk assessment. There are many risk assessments that vary in length and degree of detail. Therefore, each risk characterization is as simple or complex as the assessment from which it derives and the audience for which it is prepared. The subsequent products derived from the risk characterization will be similarly simple or complex. The purpose of a risk characterization is full disclosure, but that does not mean that you have to be wordy.

Further, each office and region produces different types of risk assessments, often producing more than one type at any given time. The differences are due to the requirements of enabling legislation, the types of decisions to be made, the culture of the office, and to other factors.

4.2.1 What is the Technical Risk Characterization?

The "technical" risk characterization is the integrating and concluding product of the risk assessment. It is the risk characterization referred to in the risk assessment paradigm and is usually within the domain of risk assessors to assemble and write. It is written with enough detailed technical information so that another expert can understand the steps taken to conduct the assessment and identify the assumptions made during the assessment. The risk characterization is able to undergo peer review. TCCR applies to the risk characterization and it fully addresses the elements discussed in Chapter 3. Example technical risk characterizations (case studies) are found in the appendices.

4.2.2 What are Risk Characterization Products I Can Prepare for Risk Managers?

The usual products prepared from the risk characterization for risk managers are generally in the form of a summary. Summaries can take various forms and you need to decide which form is the most appropriate for the particular risk manager involved and the needs of that risk manager. In general, risk managers do not need the depth of technical detail found in the technical risk characterization. They want the key issues and conclusions clearly highlighted in the summary. If risk managers want to read and understand the technical details, they can refer to the technical risk characterization or the full risk assessment.

Summary products can include:

a) Executive summary style product – at most a few pages with some technical detail for audiences with some technical knowledge, e.g., first line managers (this executive summary may sometimes be the executive summary of the technical risk characterization itself depending on the audience)

b) Bulleted list highlighting the key issues and conclusions culled from the technical risk characterization – probably 1 - 2 pages with little or no technical detail for audience with little or no technical knowledge, e.g., higher lever managers, decision makers

c) Briefing packages

4.2.3 What are Risk Characterization Products I Can Prepare for Other Audiences, Like the Public?

The products prepared from the risk characterization for other audiences besides risk assessors and risk managers can come in many forms. Generally, these are communication pieces with little or no technical detail, but still carry forward the key issues and conclusions more in a lay person's context than a technical context. The public is most thought of as the main audience in this regard.

Among the many forms these communication products may take are:

a) Fact sheets – more prose-like product that describes key issues and conclusions for non-technical audience, e.g., interested public

b) Press releases – another prose-like product that describes key issues and conclusions for mostly non-technical audience, e.g., affected and/or interested public

c) Slide shows – visual presentation (perhaps accompanied by audio presentation) of key issues and their context for mostly non-technical audience, e.g., affected public

d) Federal Register Notices – includes decisions, For Your Information (FYI) material

e) Public Relations (PR) Notices

f) Decision Documents – includes Reregistration Eligibility Decisions (REDs), Record of Decisions (RODs)

g) Speeches and Talks

4.3 Audiences for Risk Characterization Products

4.3.1 Who Are the Audiences for Risk Characterization Products?

While not specifically defined, they run the gamut from risk assessors through line managers to the decision makers, the Administrator (the ultimate decision maker), peer

reviewers, the scientific community, and the general public. The risk characterization product needs to be tailored to each of these specific audiences in terms of depth and detail.

Furthermore, since the work of EPA should be conducted as if in a fishbowl (transparency), the total number of audiences can be potentially limitless and can include most anyone. This will probably present a challenge to the writers of these risk characterization products, but one that needs to be met nonetheless. As these audiences are identified, additional products are tailored to their needs in terms of depth and detail.

4.3.2 Can I Use a Single Risk Characterization Product for All Audiences?

Generally, no. The technical risk characterization itself is consistent with the level of detail and complexity of the assessment conducted. However, as you characterize the assessment for various less technically oriented audiences, the subsequent products need to be tailored to those audiences. Technical science has become increasingly more precise, detailed, and specialized over the years. It is not easy for non-technical people to fully comprehend the details and nuances of the scientific data. It has even become increasingly difficult for scientists themselves to fully understand the meaning of data in scientific disciplines outside their own expertise. Therefore, the products you write from the technical risk characterization need to be tailored to the particular audience you need to communicate with.

4.3.3 How Much Technical Detail is Needed for Different Audiences?

This will depend on the audience. Generally, the use of technical terms should be minimized to help maintain clarity in a product. However, products prepared from risk characterizations use the appropriate amount of technical detail as required by each audience. For the technical risk characterization, full technical detail is expected. After all, this is the expert's integration of the scientific data. But even here, extensive use of technical detail and equations should be kept as minimal as practically possible. If great detail is needed, for instance with many equations, this material might be better suited in an appendix for other experts to examine in detail if they wish or for a peer review. Remember, enough technical detail is needed for a fellow expert (e.g., peer reviewer) to reconstruct the thinking behind the risk assessment.

For other audiences, a great deal less technical detail is appropriate. While the use of technical terms should be avoided to help maintain clarity in any product, products prepared from risk characterizations can present information with different amounts of technical detail as required by each audience (see section 4.2 above). For example, first-level risk managers may be technically competent, but have little time to review details. For this audience, a good approach would be to provide a short executive summary with the technical information included in an

appendix or reference the risk assessment itself (which would probably accompany the summary for first-level managers). Higher level managers and/or policy-makers are likely to have less technical expertise than first-level managers, so technical terms and equations appropriately may be removed from risk characterization products intended for this audience. For senior Agency officials, it may be appropriate to provide an abstracted risk characterization product of one page or less with little or no technical detail. For non-technical audiences, and especially when you communicate the characterization to the general public, write and speak in plain English (clarity!) – again, practically little or no technical detail is necessary. Note, however, synopsis and simplification do not mean simplistic products.

4.3.4 How Do I Ensure that the Irreducible Set of Risk Characterization Information is Carried Forward in All Risk Characterization Products?

Risk characterization is an integrating process that can lead to a range of products that might be written at different times by different people for different audiences. To ensure that the key messages are carried forward, peer review is an important component of the risk characterization portion of the risk assessment process, because it helps ensure the scientific integrity of the risk characterization, especially as it is distilled and simplified. At these points in time, there is a need to ensure that the key points are faithfully passed on and interpreted. Formal peer review may not be practical for small quick risk assessments, or as the risk characterization products are turned into briefings. However, each office needs to have procedures in place to ensure that as this is done, the major points of the characterization are faithfully captured.

4.4 Risk Characterization Format and Length

4.4.1 Is There a Standard Format for a Risk Characterization?

Not really. While most technical risk characterizations will look similar, a set format is not required for any particular characterization. Based on experiences from the colloquia and roundtables, a general flow for a format is suggested:

a) Executive Summary -- begin with a concise, brief summary at the beginning of the characterization

b) Context -- briefly describe the context of the risk assessment, including planning and scoping initiatives

c) Elements -- the main body of the risk characterization addresses all, or as many as possible, of the risk characterization elements outlined in Chapter 3

d) Final Conclusions -- state succinctly the key final conclusions

4.4.2 What is an Appropriate Length for a Risk Characterization?

Common sense should be used. Each risk characterization should reflect the length, depth, and breadth of the corresponding risk assessment and the audience for which it is intended. The length of a risk characterization for a screening assessment, for example, will not likely be very long due to little data or scientific knowledge. It will not probably change much when adapted for different audiences since limited information is usually available, although the language used may change in complexity. The length of a risk characterization for an intermediate or comprehensive risk assessment with much more data and technical detail will be correspondingly longer. Subsequent products from these risk characterizations will then likely take on shorter lengths for non-technical audiences. Don't forget to always include that irreducible set of key points that really makes a difference in the assessment outcome, no matter what the length.

5. INFORMING DECISION MAKERS

5.1 Overview

During the series of colloquia and roundtables with many Agency risk managers and risk assessor to implement the Risk Characterization Policy, a primary question that arose was "What is the role of science in the decision-making process for EPA?" Their major conclusion determined that while science is important to inform risk managers, there are other factors that also drive decision making. This small chapter provides a brief overview of how science is just one of the factors considered for decision making. A full discussion of the decision-making process is beyond the scope of this Handbook.

5.2 Science in Decision Making

5.2.1 Is the Risk Assessment the Single Driving Force Behind Decision Making?

While the scientific risk assessment has ostensibly been the primary factor and driving force for most regulatory and risk management decisions, it is apparent that factors in addition to scientific risk assessment (and economic analyses) play an important role in decision making. This reality is recognized by outside parties as well (e.g., NAS (1994) and the Presidential/Congressional Commission on Risk Assessment and Risk Management (1997)) that many other factors are important in environmental decision making. The scientific risk assessment and its peer review provide the sound scientific underpinnings for a decision. However, it is only one of the many factors that a decision maker considers in arriving at a final environmental decision.

5.3 Decision-Making Factors

5.3.1 What Are the Major Factors that Affect Decision Making?

Most risk management decisions are informed by a variety of factors in addition to science (Figure 5.1). In addition to the scientific factors, decisions generally involve consideration of many of these factors.

a) Scientific factors provide the basis for the risk assessment, including information drawn from toxicology, chemistry, epidemiology, ecology, mathematics, etc.

b) Economic factors inform the manager on the cost of risks and the benefits of reducing them, the costs of risk mitigation or remediation options and the distributional effects

c) Laws and legal decisions are factors that define the basis for the Agency's risk assessments, management decisions, and, in some instances, the schedule, level or methods for risk reduction

d) Social factors, such as income level, ethnic background, community values, land use, zoning, availability of health care, life style, and psychological condition of the affected populations, may affect the susceptibility of an individual or a definable group to risks from a particular stressor

e) Technological factors include the feasibility, impacts, and range of risk management options

f) Political factors are based on the interactions among branches of the Federal government, with other Federal, state, and local government entities, and even with foreign governments; these may range from practices defined by Agency policy and political administrations through inquiries from members of Congress, special interest groups, or concerned citizens

g) Public values reflect the broad attitudes of society about environmental risks and risk management

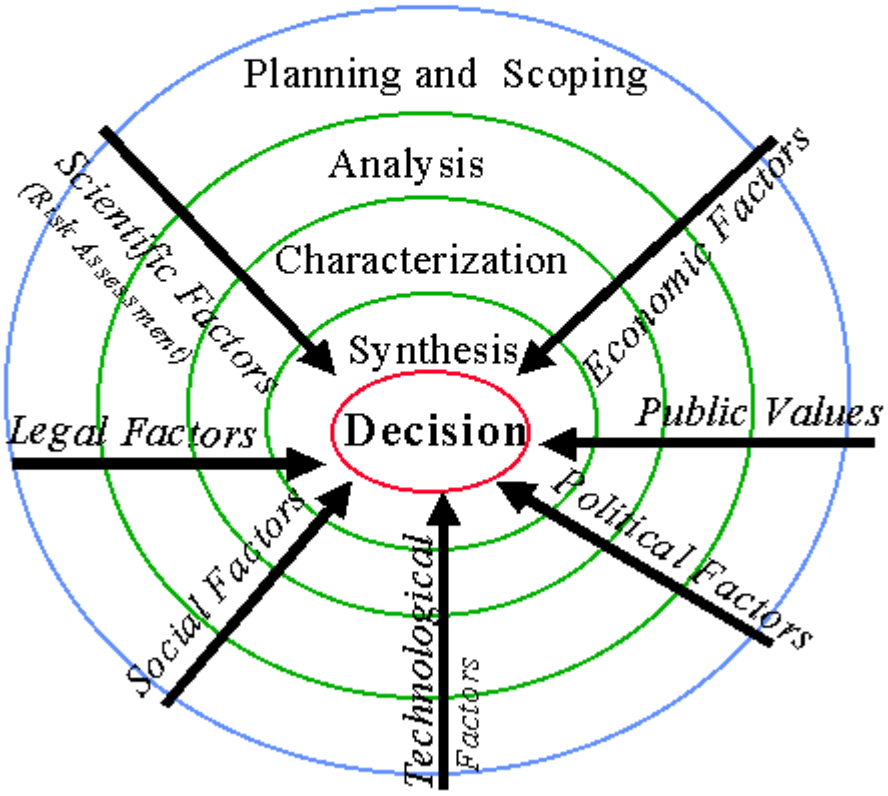

Figure 5.1 Risk Management Decision Framework. At least seven factors (represented by the arrows) affect and inform risk management decisions. Each factor passes through four analytical steps to integrate the information for a risk management decision.

5.4 Characterization of Non-Science Factors

5.4.1 Are the Economic and Other Non-Risk Assessments Subject to Characterization?

The Risk Characterization Policy applies only to clarifying the risk assessment inputs to the decision-making process. The goal of risk characterization is to openly communicate the full range of scientific considerations surrounding a risk assessment. This overarching approach can be applied to all assessments, including those of the other factors, in a general sense. A decision maker who is informed by comprehensive information, analysis, and characterization, can more easily weigh all factors to make the decision, and help the public better understand the basis for his/her decision.

5.4.2 Can the Principles of TCCR Apply to Characterizations of the Other Factors?

The principles of TCCR (transparency, clarity, consistency, and reasonableness) can be readily adapted to economic assessments/characterizations and the other factors besides risk that are characterized. It is probably desirable that the risk characterization principles apply not only to the scientific factor, but to all the factors in the way they do business.

6. ADMINISTRATIVE ISSUES

6.1 Overview

Risk characterization, as a component of risk assessment, is done by many people over time. It is often iterative in nature. Thus, risk characterizations should be memorialized in writing by the regions and offices as part of each risk assessment. If the risk assessment is done piecemeal, each risk assessment section should be accompanied by a written risk characterization for that section of the assessment. Each individual section risk characterizations can be stitched together with the other sections' risk characterizations as they are completed later to prepare the overall risk characterization of the risk assessment. Similarly, when sections of the risk assessment are updated, the risk characterization for that section should be updated too, in writing.

Decision makers are responsible for ensuring that a risk characterization is written for each risk assessment and that a risk assessment/risk characterization record is maintained.

Risk characterizations must be placed in writing.

This chapter provides an overview of the roles and responsibilities of people and organizations that write and use the risk characterization. Also, some administrative issues concerning the written risk characterization are addressed such as record keeping, budget planning, and legal considerations.

6.2 Risk Characterization Record

6.2.1 What is the Risk Characterization Record?

At its core, the risk characterization record is the written risk characterization. In addition, the record should include the planning and scoping materials, a record of the risk assessors/risk managers decisions, all parts of the risk assessment, including their individual characterizations and the final risk characterization, with any updates. It needs to be maintained in accordance with the organization's archiving procedures.

6.2.2 How Can the Risk Characterization Record Improve the Risk Characterization Process?

A good risk characterization record allows future reference to the key findings and strengths and weaknesses of the assessment. It can be studied by the risk manager to help better

inform him/her about the facts in hand at that time. In addition, a good record helps ensure that the Risk Characterization Policy is followed.

6.2.3 Where Should the Risk Characterization Record be Kept and For How Long?

During the active conduct of the risk characterization, it is likely that each risk assessor maintains the risk characterization record until his/her portion of the risk characterization is completed. Establishment and maintenance of an archive where the risk characterization records ultimately reside are an organization's responsibilities. The risk characterization record is part of the risk assessment record.

6.3 Budget Planning

As soon as it is known in the planning and scoping process that a risk assessment will be done, the resources needed to conduct the risk assessment and its characterization need to be designated. It is the risk manager's/decision maker's responsibility to ensure that the necessary resources are requested as part of the usual Agency budgetary processes. Risk characterization needs to be considered as a normal part of doing business, just as peer review should be. Risk assessment/risk characterization resource considerations should also be addressed in the analytic blueprint for Agency rulemaking actions.

6.4 Legal Considerations

6.4.1 Are There Legal Ramifications from the Risk Characterization Policy?

The Risk Characterization Policy does not establish or affect legal rights or obligations. Rather, it confirms the importance of risk characterization where appropriate, outlines relevant principles, and identifies factors Agency staff should consider in implementing the Policy. Except where provided otherwise by law, risk characterization is not a formal part of or substitute for notice and comment on rulemaking or adjudicative procedures. EPA's decision to characterize risk as part of the risk assessment in any particular case is wholly within the Agency's discretion.

6.4.2 Is Legal Advice Needed?

With respect to risk characterization **products**, it is unlikely that legal advice will be needed. However, as part of the risk characterization **process**, legal counsel, as appropriate,

should be included in the "team" supporting the decision maker and work with risk assessors, economists, and others, from planning and scoping through to the final decision.

6.5 Peer Review of Risk Characterization Handbook

A draft Risk Characterization Guide and associated case studies (i.e., Risk Characterization Handbook) were peer reviewed by a group of experts outside of EPA. EPA contracted Eastern Research Group, Inc. (ERG) to conduct the peer review (Contract No. 68-C-98-1148). ERG selected the outside experts and held a workshop, open to the public, to conduct the peer review. The workshop was held March 24-25, 1999 in Alexandria, Virginia. EPA used the comments from this public peer review, comments received from reviewers inside the Agency, and additional public comments to revise and finalize the Handbook into its current form. A summary report containing peer review comments was issued on May 21, 1999 under the auspices of the Office of Science Policy in the Office of Research and Development.

SUBJECT INDEX

This is an alphabetical listing of subjects from the Handbook and the pertinent page numbers where they are found.

- A -
  - Accountability (20)
  - Administrative issues (55)
  - Alternatives (43)
  - Analysis (10)
  - Analysis plan (29)
  - Assistant Administrators (20, 22)
  - Assumptions (11, 39)
  - Audiences (47)
- B -
  - Bias (41)
  - Branch Chiefs (22)
  - Briefing packages (46)
  - Bright line (36)
  - Budget (56)
  - Bullet list (46)
- C -
  - Chemical-specific risk assessment (20)
  - Children (38)
  - Clarity (16)
  - Communication (25)
  - Conceptual model (29)
  - Consistency (17)
  - Context (37, 49)
  - Criteria (15)
- D -
  - Decision makers (22)
  - Decision-making factors (51)
  - Division Directors (22)
  - Dose-response assessment (10)
- E -
  - Ecological risk assessment (10, 11)
  - Elements of risk characterization (35, 49)
  - Executive summary (46, 49)
  - Exposure assessment (10)
- F -
  - Fact sheets (47)
  - Factors (51)
  - Federal Register notices (47)
  - Format and length (49)
- H -
  - Hazard identification (10)
  - History (5)
  - Human health risk assessment (10, 11)
- I -
  - Implementation (8)
  - Information (24)
  - Informing Decision Makers (51)
- J -
  - Justify (24)
- K -
  - Key findings (11)
  - Key information (37)
- L -
  - Legal considerations (56)
- M -
  - Major conclusions (42, 50)
  - Manager (11)
- N -
  - NRC paradigm (10)
  - Number (13)
- O -
  - Office Director (22)

Office responsibility (25)
- P -
Peer review (14, 57)
People's roles (20)
Planning and scoping (27)
Policy choices (40)
Press releases (47)
Principles (14)
Problem formulation (10)
Public Relations notices (47)
- Q -
Quantitative risk (13)
- R -
Reasonableness (18)
Regional Administrators (20, 22)
Regulation development (13)
Regulatory negotiations (14)
Research needs (43)
Risk assessor (20)
Risk assessor/risk manager dialog (31)
Risk characterization (10)
Risk characterization criteria (14)
Risk Characterization Policy (7)
Risk characterization record (55)
Risk characterization-related products (45)
Risk communication (13)
Risk estimates (37)
Risk manager (22)
- S -
Science Policy Council (SPC) (26)
Sensitive populations (38)
Site-specific risk assessment (21)
Speeches and talks (47)
Strengths and weaknesses (41)
- T -
TCCR (1, 7, 8)
Transparency (13, 15)
Typology (31)
"Technical" risk characterization (46)
- U -
Uncertainty (24, 40)
- V -
Variability (24, 40)
Visual presentation (47)

COMMONLY USED ACRONYMS

AA	Assistant Administrator
EPA	Environmental Protection Agency
FYI	For Your Information
GPRA	Government Performance Results Act
IRIS	Integrated Risk Information System
NAS	National Academy of Sciences
NRC	National Research Council
RA	Regional Administrator
RED	Reregistration Eligibility Decision
RfC	Reference Concentration
ROD	Record of Decision
TCCR	Transparency, Clarity, Consistency and Reasonableness
TSCA	Toxic Substances Control Act

APPENDIX A

U.S. Environmental Protection Agency

POLICY FOR RISK CHARACTERIZATION

March 1995

Policy for Risk Characterization

INTRODUCTION

Many EPA policy decisions are based in part on the results of risk assessment, an analysis of scientific information on existing and projected risks to human health and the environment. As practiced at EPA, risk assessment makes use of many different kinds of scientific concepts and data (e.g., exposure, toxicity, epidemiology, ecology), all of which are used to "characterize" the expected risk associated with a particular agent or action in a particular environmental context. Informed use of reliable scientific information from many different sources is a central feature of the risk assessment process.

Reliable information may or may not be available for many aspects of a risk assessment. Scientific uncertainty is a fact of life for the risk assessment process, and agency managers almost always must make decisions using assessments that are not as definitive in all important areas as would be desirable. They therefore need to understand the strengths and the limitations of each assessment, and to communicate this information to all participants and the public.

This policy reaffirms the principles and guidance found in the Agency's 1992 policy (Guidance on Risk Characterization for Risk Managers and Risk Assessors, February 26, 1992). That guidance was based on EPA's risk assessment guidelines, which are products of peer review and public comment. The 1994 National Research Council (NRC) report, "Science and Judgment in Risk Assessment," addressed the Agency's approach to risk assessment, including the 1992 risk characterization policy. The NRC statement accompanying the report stated, "... EPA's overall approach to assessing risks is fundamentally sound despite often-heard criticisms, but the Agency must more clearly establish the scientific and policy basis for risk estimates and better describe the uncertainties in its estimates of risk."

This policy statement and associated guidance for risk characterization is designed to ensure that critical information from each stage of a risk assessment is used in forming conclusions about risk and that this information is communicated from risk assessors to risk managers (policy makers), from middle to upper management, and from the Agency to the public. Additionally, the policy will provide a basis for greater clarity, transparency, reasonableness, and consistency in risk assessments across Agency programs. While most of the discussion and examples in this policy are drawn from health risk assessment, these values also apply to ecological risk assessment. A parallel effort by the Risk Assessment Forum to develop EPA ecological risk assessment guidelines will include guidance specific to ecological risk characterization.

Policy Statement

Each risk assessment prepared in support of decision-making at EPA should include a risk characterization that follows the principles and reflects the values outlined in this policy. A risk characterization should be prepared in a manner that is clear, transparent, reasonable and consistent with other risk characterizations of similar scope prepared across programs in the Agency. Further, discussion of risk in all EPA reports, presentations, decision packages, and other documents should be substantively consistent with the risk characterization. The nature of the risk characterization will depend upon the information available, the regulatory application of the risk information, and the resources (including time) available. In all cases, however, the assessment should identify and discuss all the major issues associated with determining the nature and extent of the risk and provide commentary on any constraints limiting fuller exposition.

Key Aspects of Risk Characterization

Bridging risk assessment and risk management. As the interface between risk assessment and risk management, risk characterizations should be clearly presented, and separate from any risk management considerations. Risk management options should be developed using the risk characterization and should be based on consideration of all relevant factors, scientific and nonscientific.

Discussing confidence and uncertainties. Key scientific concepts, data and methods (e.g., use of animal or human data for extrapolating from high to low doses, use of pharmacokinetics data, exposure pathways, sampling methods, availability of chemical-specific information, quality of data) should be discussed. To ensure transparency, risk characterizations should include a statement of confidence in the assessment that identifies all major uncertainties along with comment on their influence on the assessment, consistent with the Guidance on Risk Characterization (attached). *(Note added later: the Risk Characterization Handbook replaces the Guidance on Risk Characterization)*

Presenting several types of risk information. Information should be presented on the range of exposures derived from exposure scenarios and on the use of multiple risk descriptors (e.g., central tendency, high end of individual risk, population risk, important subgroups, if known) consistent with terminology in the Guidance on Risk Characterization, Agency risk assessment guidelines, and program-specific guidance. In decision-making, risk managers should use risk information appropriate to their program legislation.

EPA conducts many types of risk assessments, including screening-level assessments of new chemicals, in-depth assessments of pollutants such as dioxin and environmental tobacco smoke, and site-specific assessments for hazardous waste sites. An iterative approach to risk assessment, beginning with screening techniques, may be used to determine if a more comprehensive assessment is necessary. The degree to which confidence and uncertainty are addressed in a risk characterization depends largely on the scope of the assessment. In general, the scope of the risk characterization should reflect the information presented in the risk assessment and program-specific guidance. When special circumstances (e.g., lack of data, extremely complex situations, resource limitations, statutory deadlines) preclude a full assessment, such circumstances should be explained and their impact on the risk assessment discussed.

Risk Characterization in Context

Risk assessment is based on a series of questions that the assessor asks about scientific information that is relevant to human and/or environmental risk. Each question calls for analysis and interpretation of the available studies, selection of the concepts and data that are most scientifically reliable and most relevant to the problem at hand, and scientific conclusions regarding the question presented. For example, health risk assessments involve the following questions:

> Hazard Identification -- What is known about the capacity of an environmental agent for causing cancer or other adverse health effects in humans, laboratory animals, or wildlife species? What are the related uncertainties and science policy choices?
>
> Dose-Response Assessment -- What is known about the biological mechanisms and dose-response relationships underlying any effects observed in the laboratory or epidemiology studies providing data for the assessment? What are the related uncertainties and science policy choices?
>
> Exposure Assessment -- What is known about the principal paths, patterns, and magnitudes of human or wildlife exposure and numbers of persons or wildlife species likely to be exposed? What are the related uncertainties and science policy choices?

Corresponding principles and questions for ecological risk assessment are being discussed as part of the effort to develop ecological risk guidelines.

Risk characterization is the summarizing step of risk assessment. The risk characterization integrates information from the preceding components of the risk assessment and synthesizes an overall conclusion about risk that is complete, informative and useful for decision makers.

Risk characterizations should clearly highlight both the confidence and the uncertainty associated with the risk assessment. For example, numerical risk estimates should always be accompanied by descriptive information carefully selected to ensure an objective and balanced characterization of risk in risk assessment reports and regulatory documents. In essence, a risk characterization conveys the assessor's judgment as to the nature and existence of (or lack of) human health or ecological risks. Even though a risk characterization describes limitations in an assessment, a balanced discussion of reasonable conclusions and related uncertainties enhances, rather than detracts, from the overall credibility of each assessment.

"Risk characterization" is not synonymous with "risk communication." This risk characterization policy addresses the interface between risk assessment and risk management. Risk communication, in contrast, emphasizes the process of exchanging information and opinion with the public – including individuals, groups, and other institutions. The development of a risk assessment may involve risk communication. For example, in the case of site-specific assessments for hazardous waste sites, discussions with the public may influence the exposure pathways included in the risk assessment. While the final risk assessment document (including the risk characterization) is available to the public, the risk communication process may be better served by separate risk information documents designed for particular audiences.

Promoting Clarity, Comparability and Consistency

There are several reasons that the Agency should strive for greater clarity, consistency and comparability in risk assessments. One reason is to minimize confusion. For example, many people have not understood that a risk estimate of one in a million for an "average" individual is not comparable to another one in a million risk estimate for the "most exposed individual." Use of such apparently similar estimates without further explanation leads to misunderstandings about the relative significance of risks and the protectiveness of risk reduction actions.

EPA's Exposure Assessment Guidelines provide standard descriptors of exposure and risk. Use of these terms in all Agency risk assessments will promote consistency and comparability. Use of several descriptors, rather than a single descriptor, will enable EPA to

present a fuller picture of risk that corresponds to the range of different exposure conditions encountered by various individuals and populations exposed to most environmental chemicals.

Legal Effect

This policy statement and associated guidance on risk characterization do not establish or affect legal rights or obligations. Rather, they confirm the importance of risk characterization as a component of risk assessment, outline relevant principles, and identify factors Agency staff should consider in implementing the policy.

The policy and associated guidance do not stand alone; nor do they establish a binding norm that is finally determinative of the issues addressed. Except where otherwise provided by law, the Agency's decision on conducting a risk assessment in any particular case is within the Agency's discretion. Variations in the application of the policy and associated guidance, therefore, are not a legitimate basis for delaying or complicating action on Agency decisions.

Applicability

Except where otherwise provided by law and subject to the limitations on the policy's legal effect discussed above, this policy applies to risk assessments prepared by EPA and to risk assessments prepared by others that are used in support of EPA decisions.

EPA will consider the principles in this policy in evaluating assessments submitted to EPA to complement or challenge Agency assessments. Adherence to this Agency-wide policy will improve understanding of Agency risk assessments, lead to more informed decisions, and heighten the credibility of both assessments and decisions.

Implementation

Assistant Administrators and Regional Administrators are responsible for implementation of this policy within their organizational units. The Science Policy Council (SPC) is organizing Agency-wide implementation activities. Its responsibilities include promoting consistent interpretation, assessing Agency-wide progress, working with external groups on risk characterization issues and methods, and developing recommendations for revisions of the policy and guidance, as necessary.

Each Program and Regional office will develop office-specific policies and procedures for risk characterization that are consistent with this policy and the associated guidance. Each

Program and Regional office will designate a risk manager or risk assessor as the office representative to the Agency-wide Implementation Team, which will coordinate development of office-specific policies and procedures and other implementation activities. The SPC will also designate a small cross-Agency Advisory Group that will serve as the liaison between the SPC and the Implementation Team.

In ensuring coordination and consistency among EPA offices, the Implementation Team will take into account statutory and court deadlines, resource implications, and existing Agency and program-specific guidance on risk assessment. The group will work closely with staff throughout Headquarters and Regional offices to promote development of risk characterizations that present a full and complete picture of risk that meets the needs of the risk managers.

/s/

APPROVED:_____ DATE: MAR 21 1995

Carol M. Browner, Administrator

APPENDIX B

WAQUOIT BAY CASE STUDY

The Waquoit Bay case study is not a complete risk characterization. It is an example of the beginning of the ecological risk assessment process that includes a problem formulation summary and a proposed risk characterization based on the planning and scoping for this risk assessment.

Contents

EXECUTIVE SUMMARY . . . . . Page B-4

1. CONTEXT . . . . . Page B-6
   - 1.1 The Watershed . . . . . Page B-7
   - 1.2 The Watershed Case Study Team . . . . . Page B-8
   - 1.3 Problem Formulation . . . . . Page B-9
     - 1.3.1 Planning and Selection of Management Goals and Objectives . . Page B-9
     - 1.3.2 Assessment Endpoints . . . . . Page B-10
     - 1.3.3 Conceptual Model . . . . . Page B-11
     - 1.3.4 Analysis . . . . . Page B-11

2. RISK PARADIGM . . . . . Page B-14
   - 2.1 Measures of Exposure . . . . . Page B-14
     - 2.1.1 Estimating Nitrogen Load from Watershed and Subwatersheds . . . . . Page B-14
     - 2.1.2 Validating the Nitrogen-Loading Model . . . . . Page B-15
   - 2.2 Measures of Effects of Nitrogen on Eelgrass . . . . . Page B-16
   - 2.3 Calculations and Uncertainties . . . . . Page B-17
     - 2.3.1 Risk Elements . . . . . Page B-17
     - 2.3.2 Integrating Nitrogen Exposure with Eelgrass Response . . . . . Page B-17
     - 2.3.3 Predicting Eelgrass Recovery Under Different Nitrogen-Loading Scenarios . . . . . Page B-18
     - 2.3.4 Additional Effects of Other Stressors on Eelgrass . . . . . Page B-18

3. CONCLUSIONS . . . . . Page B-19

4. RECOMMENDATIONS REGARDING DATA GAPS . . . . . Page B-19
   - 4.1 Other Stressors Affect Valued Resources . . . . . Page B-19

5. LITERATURE CITATIONS . . . . . Page B-20

Tables

Table 1. The Waquoit Bay Watershed Management Goal, Interpreted as 10 Management Objectives . . . . . Page B-9
Table 2. Impact Matrix for the Waquoit Bay Watershed . . . . . Page B-12
Table 3. Stressor Rankings Based on Overall Effects on All Assessment Endpoints . . Page B-12

Table 4. Estimates of Percent Nitrogen Loading from Atmosphere, Fertilizer, and Wastewater to Waquoit Bay . . . . . Page B-15

Figures

Figure 1a. Conceptual model of the Waquoit Bay watershed ecological risk assessment. This portion shows land use activities and stressors . . . . . Page B-22
Figure 1b. Conceptual model of the Waquoit Bay watershed ecological risk assessment. This portion shows how stressors may interact with the ecological system to cause effects on valued resources . . . . . Page B-24
Figure 2. Differences in arrival time of nitrogen between the static and dynamic nitrogen loading models . . . . . Page B-25
Figure 3. Changes in nitrogen loading alter the relative contribution of primary producers to total production in shallow estuaries . . . . . .Page B-26
Figure 4. Hypothetical response of eelgrass to increases in nitrogen load . . . . . Page B-27
Figure 5. Hypothetical relationship between the probable extent of eelgrass habitat and nitrogen loading under high and low uncertainty . . . . . Page B-28

Waquoit Bay Watershed Ecological Risk Assessment: Problem Formulation Summary and Proposed Risk Characterization

EXECUTIVE SUMMARY

Context

EPA sponsored the Waquoit Bay ecological risk assessment to evaluate the impact of stressors introduced by human activities and to provide resource managers with viable options to protect the Bay.

Waquoit Bay is a small estuary on the south coast of Cape Cod, Massachusetts. Its watershed covers approximately 53 square kilometers (21 square miles) of freshwater streams and ponds, salt ponds and marshes, pine and oak forests, barrier beaches, and open estuarine waters. Waquoit Bay is in the fastest growing county in the state, and as the human population grows, so does pressure on the valuable natural resources that have attracted people to the area.

This document presents only the problem formulation for the risk assessment, along with summary information and a proposed plan for estimating risk.

Problem Formulation

Local resource managers identified a goal to reestablish and maintain water quality and habitat conditions in Waquoit Bay and associated wetlands, rivers and ponds. Based on this goal, a risk assessment team identified 10 management objectives that they believed were required to achieve the goal. They then presented the objectives to the risk managers for their consideration and approval.

The risk assessment team conducted a comparative risk analysis to help set priorities to determine which stressors, assessment endpoints, and relationships should be examined further. Stakeholders in the state helped identify the assessment endpoints, which include both an entity (e.g., eelgrass) and a measurable attribute (e.g., distribution). These endpoints provide direction for the assessment as well as a basis for the development of questions, predictions, models, and analyses. After the team selected a focus for the assessment, it determined appropriate exposure and effects measures and models and described the approaches to characterizing risks.

The comparative risk analysis identified nitrogen loading as a primary stressor in estuarine habitats of the Waquoit watershed; submerged aquatic vegetation, specifically eelgrass

(*Zostera marina*) habitat was identified as the most important assessment endpoint. Numerous studies have shown that eelgrass meadows provide a very good habitat for many commercially and recreationally important fish and shellfish. Therefore, protecting eelgrass protects fish and invertebrate species.

Eelgrass requires a lot of light to grow. In Waquoit Bay, increased phytoplankton (microscopic one-celled organisms) and seaweed populations, fueled by the addition of nitrogen from coastal development, have decreased the amount of light penetrating the water. In 1951, eelgrass meadows covered most of Waquoit Bay and its adjoining coastal ponds and rivers. Today, eelgrass is absent from the Bay and has declined significantly in the adjoining tributaries and ponds. Species dependent on eelgrass, particularly scallops, have likewise decreased.

Although it has been known that nitrogen loading contributes to the loss of submerged aquatic vegetation, predictive relationships between nitrogen sources and loading and biological response have not been developed for estuaries, such as Waquoit Bay. Because of these findings and due to the constraints of limited data to assess other endpoints, the risk assessment focused on the risk to eelgrass habitat from nitrogen loading from the adjacent watershed.

Risk Paradigm

The analysis plan involved estimating the loading of nitrogen to the watershed/estuary (measures of exposure), and evaluating how a given load of nitrogen directly or indirectly impacts eelgrass habitat (measures of effects).

Exposure

The team used a nitrogen-loading model to estimate the amount of nitrogen that arrives at the edge of the estuary. This model showed that of the three major contributors to nitrogen over-loading—atmospheric deposition, septic systems, and fertilizer use—septic systems are the largest source of nitrogen to the estuary. The team verified the model predictions against actual measurements of nitrogen in groundwater about to enter the estuary. The team also found that model predictions of nitrogen coming from wastewater agreed with stable isotopic ratios of nitrogen in groundwater.

Effect

Increases in nitrogen change the composition of primary plant producers, such as eelgrass, seaweed, and phytoplankton, in receiving waters. The team used the estuarine simulation model to predict the response of different plant producers to increasing nitrogen loads.

The stressor-response relationship was defined by plotting nitrogen-loading rates provided by the static and dynamic loading models against measures of ecological effect. The deleterious effect of excess nitrogen on eelgrass in shallow coastal bays is primarily an indirect one; nitrogen stimulates the rapid growth of phytoplankton and seaweed. Therefore, analyzing the effects of nitrogen on eelgrass first requires estimating its effects on algae growth and other intermediates.

Calculations and Uncertainties

The risk assessment team will estimate the risk by integrating the output from the nitrogen-loading models with the predictions of the ecological response model. With knowledge of the location of houses and of groundwater travel times, it will be possible to estimate how much nitrogen can be removed under different management scenarios and how much longer the rest of the nitrogen will remain in the aquifer traveling to the Bay. However, that information alone will not be sufficient to predict the time when water quality conditions can support eelgrass. The contribution of benthic processes and sediment conditions also must be considered. These parameters increase the uncertainty surrounding the ability to estimate time to recovery.

If nitrogen were reduced and eelgrass were to reestablish itself or be replanted, other stressors, such as dredging activities, dock construction over eelgrass beds, and propeller scour from passing boats, may become important. As funding permits, relationships among other stressors and valued resources will be evaluated.

4. CONTEXT

This document includes summary information from the planning and problem formulation report produced for the Waquoit Bay ecological risk assessment case study and a description of the planned risk characterization component of the risk assessment.

EPA sponsored the Waquoit Bay watershed ecological risk assessment to evaluate the danger to valued water resources from stressors caused by human activities, and to provide resource managers with viable options to protect the resources. A qualitative risk analysis identified nitrogen loading as a primary stressor in estuarine habitats of the watershed and eelgrass habitat as the most important assessment endpoint. Because of these findings and due to constraints of limited data to assess other endpoints, the risk assessment focused on the risk to eelgrass habitat from nitrogen loading from the adjacent watershed.

The goal of the Waquoit Bay ecological risk assessment is to provide managers with answers to key questions:

a) What are the sources of nutrients and their relative contributions?

b) What will be the effects of different degrees of nutrient reduction?

1.1 The Watershed

Waquoit Bay is a small estuary on the south coast of Cape Cod, Massachusetts. Its watershed covers about 53 square kilometers (21 square miles) of freshwater streams and ponds, salt ponds and marshes, pine and oak forests, barrier beaches, and open estuarine waters. The land and water are home, spawning ground, and nursery for plant and animal life including piping plovers, least terns (endangered birds), the sandplain gerardia (an endangered plant), alewife, winter flounder, blue crab, scallops and clams, and other fish species that migrate through the estuary. Initially valued for hunting, farming, and fishing, Waquoit Bay now primarily provides aesthetic and recreational opportunities, demands that have generated residential development and business for local marine-dependent industries.

Cape Cod's economic viability is largely dependent on tourists who are drawn to the sandy beaches, seafood restaurants, boating opportunities, and water recreation areas. Thus the economy on Cape Cod and the environment on Cape Cod are mutually inter-dependent. The once rural surroundings have become increasingly suburbanized as bedroom and retirement communities have sprung up. Barnstable County, where the Waquoit Bay watershed is located, is the fastest growing county in Massachusetts. As the population grows, so does pressure on the valuable natural resources that have attracted people to the area.

Living in bottom sediments of shallow embayments of the northwestern Atlantic is a flowering plant known as eelgrass (*Zostera marina*). Numerous studies have shown that submerged aquatic vegetation, such as eelgrass meadows provide a very good habitat for many commercially and recreationally important fish and shellfish. Eelgrass needs a lot of light to grow. In Waquoit Bay, increased phytoplankton (microscopic one-celled organisms) and seaweed populations, fueled by the addition of nitrogen from coastal development, have decreased the amount of light penetrating the water. In 1951, eelgrass meadows covered most of Waquoit Bay proper and its adjoining coastal ponds and rivers. Today, eelgrass is absent from the Bay proper and has declined significantly in the adjoining tributaries and ponds. Species dependent on eelgrass, particularly scallops, have likewise decreased. In 1987, 1988, and 1990, fish kills occurred in Waquoit Bay, and the northern beach was covered with thousands of dead winter flounder, shrimp, blue crabs, and other estuarine species.

In Ashumet and Johns Ponds, blooms of phytoplankton have changed the color of the water and depleted oxygen levels in the bottom waters of the pond. Fish kills occurred in Ashumet Pond in 1985 and 1986.

The Massachusetts Military Reservation, a Superfund site within the watershed of Waquoit Bay, is the source of several plumes of toxic chemicals that threaten drinking water supplies.

As with many coastal areas where marine recreation is important, the number of boats and request for permits to build docks have increased in the Waquoit Bay area. Resuspended sediments from boating activities, toxic chemicals from pressure treated wood in docks, propeller scarring from boat motors, and shading of eelgrass beds from docks are all potential sources of stress to valuable marine resources.

Concern about the effects of development on Cape Cod have led to several initiatives. Among these have been the creation of a regional planning agency, the Cape Cod Commission, that has authority over developments of regional impact; the work of the Association for the Preservation of Cape Cod, which has contributed to the protection of the Cape's drinking water supply, among other issues; the efforts of the Waquoit Bay Land Margin Ecosystem Research Project, a multi-institutional, interdisciplinary program that has contributed to our knowledge of the problem of nitrogen overloading; the designation of a U.S. Fish and Wildlife Refuge in parts of the Waquoit Bay watershed, which will remove many areas from development; the designation of the Waquoit Bay area as an Area of Critical Environmental Concern, a Massachusetts designation that provides for special scrutiny to any alterations that might impact natural resources; and the designation of the Waquoit Bay National Estuarine Research Reserve that also serves to protect the resources of the Bay and its adjacent lands.

1.2 The Watershed Case Study Team

The EPA-sponsored ecological risk assessment underway in the Waquoit Bay watershed builds on the above efforts by creating a mechanism to integrate the results of various research and planning efforts into management options for local coastal decision-makers. The Waquoit Bay watershed was selected as one of several EPA-sponsored ecological risk assessment case studies because of interest by local, state, and federal organizations in the watershed, the type of watershed (estuarine), the diversity of stressors (e.g., nutrients, toxic chemicals, obstructions, altered flow), a substantial existing database, and willingness by the Waquoit Bay National Estuarine Research Reserve (WBNERR) and EPA Region 1 to lead the risk assessment team.

The prior activities and current and planned work of the risk assessment are described in the following sections that emphasize the major elements of planning and problem formulation (management goal development, selecting assessment endpoints, preparing a conceptual model, and producing an analysis plan) and a proposed risk estimation.

1.3 Problem Formulation

1.3.1 Planning and Selection of Management Goals and Objectives

The management goal was developed through a multistep planning process initiated and completed by the team. The process included a public meeting to initiate the process, evaluation of goals by interested organizations in the watershed, and a meeting of members of these organizations to review and approve the management goal and team-derived objectives. The management goal is a qualitative statement that captures essential interests expressed by different management organizations and the public in the Waquoit Bay watershed. The goal developed for the Waquoit Bay watershed risk assessment through community involvement is:

> *Reestablish and maintain water quality and habitat conditions in Waquoit Bay and associated wetlands, freshwater rivers, and ponds to (1) support diverse, self-sustaining commercial, recreational, and native fish and shellfish populations and (2) reverse ongoing degradation of ecological resources in the watershed.*

In order for the management goal to support an ecological risk assessment, the risk assessment team evaluated the goal and interpreted it as 10 management objectives believed to be required to achieve the goal (see Table 1). The objectives were intended to state explicitly the management results implied in the general goal statement. By performing this kind of evaluation, the team provided feedback to the managers on the ecological characteristics of the goal, developed a systematic process for identifying assessment endpoints that could be directly linked to the management goal, and provided a way to measure achievement of the goal for risk managers.

Table 1. The Waquoit Bay Watershed Management Goal, Interpreted as 10 Management Objectives.

Affected Area	Number	Component Management Objective
Estuarine and Freshwater	1	Reduce or eliminate hypoxic or anoxic events
	2	Prevent toxic levels of contamination in water, sediments, and biota
	3	Restore and maintain self-sustaining native fish populations and their habitat
Estuarine	4	Reestablish viable eelgrass beds and associated aquatic communities in the Bay

	5	Reestablish a self-sustaining scallop population in the Bay that can support a viable sport fishery
	6	Protect shellfish beds from bacterial contamination that results in closure
	7	Reduce or eliminate nuisance macroalgal growth
Freshwater	8	Prevent eutrophication of rivers and ponds
	9	Maintain diversity of native biotic communities
	10	Maintain diversity of water-dependent wildlife

Table 1 is partitioned into three categories. The "Estuarine and Freshwater" category includes three objectives that are common to both surface water types. Four objectives under the "Estuarine" category and three objectives under the "Freshwater" category are unique to those waters. The 10 objectives are stated as goals for specific aspects of exposure, stressors, and valued ecological resources. Assessment endpoints were selected and justified based on these objectives. Although risk managers developed the goal, the specific management objectives were generated by the team based on available information on watershed resources. The objectives were then provided to the risk managers for their consideration and approval.

1.3.2 Assessment Endpoints

Following the assessment of available information for the watershed, the team selected eight assessment endpoints that directly link management goals to measurable ecological values in the watershed. Assessment endpoints are measurable attributes of valued resources identified by the stakeholders that represent ecologically important components of the ecosystems. Assessment endpoints include both an entity (e.g., eelgrass) and a measurable attribute (e.g., distribution), and they provide direction for the assessment as well as a basis for the development of questions, predictions, models, and analyses. The first seven endpoints (below) that the team selected represent ecological concerns about estuarine and freshwater components of the ecosystem.

1) Estuarine eelgrass habitat abundance and distribution
2) Resident and juvenile nursery estuarine finfish species diversity and abundance
3) Estuarine benthic invertebrate diversity, abundance, and distribution
4) Migratory (stream) fish reproduction
5) Freshwater stream assemblages, diversity, and abundance
6) Freshwater pond trophic status
7) Wetlands habitat
8) Barrier beach habitat

1.3.3 Conceptual Model

Devised by the ecological risk assessment team with input from stakeholders, the general watershed conceptual model (Figure 1a and b) is a broad representation of relationships among human activities in the watershed (sources), the stressors believed to occur as a result of those sources, and ecological effects likely to occur in each of the assessment endpoints. The pathways from sources of stressors to valued resources are actually risk hypotheses that can be analyzed during the ecological risk assessment process.

Because eelgrass is the foundation for the estuarine community and because its presence indicates good water quality, it was targeted as a high priority assessment endpoint in this ecological risk assessment (Figure 1a and b).

1.3.4 Analysis

Problem formulation concludes with the development of an analysis plan. For the Waquoit Bay ecological risk assessment, the risk assessment team first conducted a comparative risk analysis to help prioritize which stressors, assessment endpoints, and relationships should be examined further. Once a focus for the assessment was selected, the team determined appropriate exposure and effects measures and models and described the approaches to characterizing risks.

Comparative Risk Analysis

To help focus the risk assessment, the risk assessment team ranked stressors in terms of their potential risk to all resources in the watershed using a "fuzzy set" decision analysis method based on best professional judgment (Harris et al., 1994). The analysis ranked the stressors in order of greatest overall contribution of risk to the endpoints, based on an ordinal effect of a stressor on that endpoint, ranging from no effect to severe effect. For example, in Table 2, the effect of nutrients on eelgrass habitat is assigned a 3 (severe indirect effect), but the effect of physical alteration on eelgrass habitat is considered a 1 (slight effect).

The results of the comparative analysis ranked nutrients as the primary stressor in the watershed followed by physical alteration of habitat, flow alteration, harvest pressure, resuspended particulates, and toxic chemicals (Tables 2, 3).

Table 2. Impact Matrix for the Waquoit Bay Watershed. Each cell represents the estimated effect of a stressor on an endpoint, on an ordinal scale from 0 (no effect) to 3 (severe effect).

	Assessment Endpoints							
Stressors	Migratory Fish	Fresh-water Biota	Wetland Habitat	Pond Trophic Status	Eelgrass Habitat	Estuarine Inverte-brates	Estuarine Fish	Barrier Beaches
Toxic Chemicals	1	1	1	0	0	1	1	0
Altered Flow	3	2	2	0	0	0	1	0
Resuspended Particulates	1	1	1	0	1	1	1	0
Nutrients	1	1	1	3	3	2	2	0
Physical Alteration	1	1	1	0	2	1	1	2
Harvest Pressure	2	1	0	0	0	2	2	0

Table 3. Stressor Rankings Based on Overall Effects on All Assessment Endpoints.

Stressors	**Unweighted**	**Weighted for Persistence**	**Weighted for Persistence and Interaction**
Nutrients	1	1	1
Physical Alteration of Habitat	2	2	2
Altered Flow	3	3	3
Toxic Chemicals	4	4	4
Harvest Pressure	5	5	5
Resuspended Particulates	6	6	6

The comparative analysis established that nutrients affected three assessment endpoints in the estuarine system to different degrees: eelgrass habitat (severe effect), estuarine invertebrates (moderate effect), and estuarine fish (moderate effect). These assessment endpoints are inter-related because eelgrass meadows provide habitat to both estuarine fish and invertebrate species. Therefore, protecting eelgrass will protect fish and invertebrate species.

The comparative analysis ranked other stressors to eelgrass in addition to nutrients: resuspended particulates (minor effect) and physical alteration of habitat (moderate effect). The team concluded that these stressors were not as important for reasons discussed below.

Although rivers enter Waquoit Bay, they do not carry a sediment load because rivers on Cape Cod are fed by groundwater and are really drains for the aquifer. The particle size and composition of the Cape's sandy glacial soils are such that any suspended particles sediment out, and the sandy soils quickly absorb precipitation so there is very little surface runoff.

The resuspended particles in waters of Waquoit Bay are organic matter from decaying algae, plants, and other estuarine organisms. Studies of particle settling following passage of boats whose motors disrupt the bottom show that the particles very quickly settle out. Although there are many boats on the Bay and adjacent tributaries and ponds on weekends. Little boat traffic occurs during weekdays. Docks and marinas, where heavy boat use is expected, comprise only a very small part of the surface area of the Waquoit Bay estuarine complex.

Physical alteration of habitat due to activities, such as shellfish harvesting, motor boat operation, and construction of docks can fragment or eliminate eelgrass habitat. The number, frequency, and placement of these activities are such that deleterious effects would be restricted to a small area of the overall estuarine complex.

Focus of Analysis Plan

The team concluded that reducing nutrient loads to restore water quality to conditions that would support eelgrass growth was the most important stressor-endpoint relationship to evaluate and that less critical stressors, such as resuspended particulates and physical alteration of habitat, would be important to monitor and assess once water quality was improved via reducing the nutrient load.

Therefore, the risk assessment team decided to focus on one stressor (nitrogen) and one assessment endpoint (eelgrass) based on the results of the comparative analysis and also on limitations of data and funding. Many other valued resources in the estuarine waters utilize eelgrass beds. For example, juvenile scallops attach to eelgrass blades, reducing their risk from predators. Winter flounder spawn in eelgrass meadows. The team believed that focusing on eelgrass distribution would encompass risks to other valued resources.

Although it has been known for some time that nitrogen loading contributes to estuarine eutrophication and loss of submerged aquatic vegetation in Waquoit Bay and other estuaries of Cape Cod, predictive relationships between nitrogen sources and loading and the biological

response of the estuary have not been developed for estuaries, such as Waquoit Bay. The objective of this analysis is to develop a link between modeled estimates of nitrogen loading and predicted ecological effects in the estuary.

The analysis plan to evaluate risk from nitrogen loading to eelgrass habitat involves (1) estimating the loading of nitrogen to the watershed and estuary (measures of exposure), and (2) evaluating how a given load of nitrogen directly or indirectly impacts eelgrass habitat (measures of effects). These analyses are performed on subwatersheds and their adjacent estuaries that have experienced different degrees of development resulting in different amounts of nitrogen entering the estuaries. Information about past and present land use is employed to forecast future changes in the estuary in response to future loads of nitrogen.

2. RISK PARADIGM

2.1 Measures of Exposure

2.1.1 Estimating Nitrogen Load from Watershed and Subwatersheds

The hypothesis underlying this part of the analysis is that development on coastal watersheds increases the amount of nitrogen entering coastal waters. On Cape Cod, the number of houses has been positively related to the median amount of nitrate measured in groundwater (Persky, 1986). Nitrogen in groundwater eventually travels to receiving waters of the Waquoit Bay estuarine complex.

The analysis relies on a nitrogen-loading model to estimate the amount of nitrogen that arrives at the edge of the estuary (Valiela et al., 1997). The model sums all nutrient loads, subtracts losses during transport, and yields a value for nitrogen arriving at the edge of the estuary (or salt marsh). The nitrogen-loading model includes more than 50 input terms (e.g., number of houses, area in agriculture, amount of nitrogen fertilizer applied to lawns, per capita contribution of nitrogen to septic systems, percent loss of nitrogen in septic systems, percent loss of fertilizer nitrogen).

Many of the parameters in the nitrogen-loading calculation are very uncertain. For example, the amount of nitrogen lost in septic systems on sandy soils like those on Cape Cod ranges from 10-90% (Valiela et al., 1997). Estimates of the contribution of dry deposition and of dissolved organic nitrogen to the total amount of atmospheric nitrogen are also highly uncertain due to limited sampling and analyses. Estimates of uncertainty surrounding model inputs and outputs have been calculated (Collins et al. submitted) and will be applied to the final nitrogen-loading values.

Because groundwater travels approximately 100 meters per year in the watershed, there is a lag between the time of development and the time that nitrogen arrives at the estuary. The nitrogen-loading model can be run in dynamic mode to determine the actual load of nitrogen arriving at the estuary at any given time (Figure 2). The nitrogen-loading model can also be run in static or dynamic mode using historic land use information to hindcast nitrogen loading and under a variety of future build-out scenarios to predict future loading and effects.

Within the Waquoit Bay watershed are several subwatersheds that can, in turn, be divided into recharge areas. The load of nitrogen can be estimated for the entire watershed or its component parts.

The nitrogen-loading model shows that atmospheric deposition, septic systems, and fertilizer use are the three major contributors to nitrogen overloading (Table 4). Although more nitrogen is delivered to the watershed from the atmosphere, much of that nitrogen is taken up by vegetation, soils, and the aquifer during travel to the estuary. Septic systems are the largest source of nitrogen to the estuary (Valiela et al., 1997). The relative contribution of these three sources are important to local coastal decision-makers since the source of most of the atmospheric nitrogen is far outside the watershed.

Table 4. Estimates of Percent Nitrogen Loading from Atmosphere, Fertilizer, and Wastewater to Waquoit Bay.

Source	Percent to Watershed	Percent to Estuary
Atmospheric deposition	56	30
Septic system	27	48
Fertilizers	14	15
Upper ponds	2	8

2.1.2 Validating the Nitrogen-Loading Model

Modeled predictions of the load of nitrogen to the edge of the estuary were validated in two ways. First the model predictions were verified against actual measurements of nitrogen in groundwater about to enter estuaries. As with model predictions, there is uncertainty associated with the groundwater measures. Second, model predictions of wastewater nitrogen were compared to stable isotopic ratios of nitrogen in groundwater. The predictions of nitrogen coming from wastewater agreed with the values derived from stable isotopes.

The nitrogen-loading model predicts a concentration of nitrogen arriving at the edge of a salt marsh (if present) or at the edge of the water, but a correction is necessary to estimate the amount of nitrogen actually available to primary producers in the water. A biological process (denitrification) that occurs within salt marshes can reduce the amount of nitrogen that finally enters the Bay. Salt marsh areas and data on denitrification in Waquoit Bay sediments are used to estimate the potential interception of land-derived nitrogen. These terms are applied as correction terms to the model predictions. Water column nutrient and salinity data from different estuarine reaches are used to estimate losses or gains of nitrogen in excess of dilution during down-estuary transport.

The validated estimates of nitrogen from the watershed minus losses in marshes and sediments and during travel down the river yield an amount of nitrogen available to the primary producers in the estuary(ies).

2.2 Measures of Effects of Nitrogen on Eelgrass

As is shown in the conceptual model (Figure 1), the deleterious effect of excess nitrogen on eelgrass, which requires a lot of light, in shallow coastal bays is primarily an indirect one. Phytoplankton shade the water column, and seaweed grow over, shade, and displace the eelgrass. Therefore, to analyze effects of nitrogen on eelgrass requires first estimating the effects on algae growth and other intermediates. To these are added physical and temporal factors of the estuarine system that affect nutrient availability and other aspects of plant growth.

The analysis utilizes an estuarine model to simulate the effects of nitrogen inputs, water residence time, mixing in the water, and seasonal changes in light and temperature on the system metabolism of phytoplankton, seaweed, and eelgrass. The model compares responses (especially eelgrass decline) to different nitrogen-loading rates across a variety of subestuaries. The influence of any one subestuary on another, or on the whole Waquoit Bay system, is assessed. Model output is validated with data from estuaries not used in development of the model.

Increases in nitrogen change the mix of primary producers (plants such as eelgrass, seaweed, and phytoplankton) in receiving waters. The estuarine simulation model predicts the response of different producers to increasing nitrogen loads (Figure 3).

The nitrogen-loading model and estuarine system model can be performed under a variety of nitrogen-loading scenarios (e.g., build-out) in an attempt to hindcast and forecast loading and response. As new information becomes available during the analysis phase of the risk assessment, the models can be updated.

2.3 Calculations and Uncertainties

No risk calculations are available at this time. Research in Waquoit Bay and elsewhere suggests that development in coastal watersheds increases the amount of nitrogen entering coastal watersheds and their adjacent waters. On Cape Cod, the nitrate concentration in groundwater is higher below developed landscapes than below naturally vegetated areas (Persky 1986). The nitrogen in groundwater travels to coastal bays where it fertilizes vegetation. Research shows that once in coastal bays nitrogen is rapidly taken up by some species of algae (phytoplankton and seaweed) increasing their growth rates. These algae shade the water column so less light reaches the bottom.

Thus, increased loads of nitrogen from coastal development leads to overgrowth of opportunistic species of algae that alter the functioning of the estuarine system. These alterations include changes in water chemistry (e.g., dissolved oxygen concentration), habitat loss, and abundance of some species.

2.3.1 Risk Elements

To define the stressor-response relationship, nitrogen-loading rates provided by the static and dynamic loading models will be plotted against measures of ecological effects. Achieving low nitrogen loading to Waquoit Bay will require nitrogen source control, as well as a sufficient time lag to allow nitrogen currently in the groundwater to be flushed out. The travel times of groundwater vary across the watershed, thus, nitrogen loading to the estuary is not a function of land use at any one point in time. The two sets of models and their estimated uncertainties can be used to predict the effects of different nutrient management scenarios for Waquoit Bay using information about the groundwater travel time, location of houses in the watershed, time to remove different percentages of nitrogen, and the time required for the remaining nitrogen to travel to the estuary.

Septic systems and fertilizers are two local sources of nitrogen, but atmospheric deposition can originate hundreds of miles from the Waquoit Bay watershed. Viable options to reduce nitrogen to the extent necessary to improve water quality will depend on the relative contributions of different nitrogen sources, the amount of nitrogen that needs to be eliminated, and the uncertainty surrounding that estimate.

2.3.2 Integrating Nitrogen Exposure with Eelgrass Response

Risk characterization will include integration of the output from the nitrogen-loading models with the predictions of the ecological response model (see Section 2.1 for description of

individual models). The response of eelgrass to effects of increased nitrogen can be depicted as in Figure 4.

2.3.3 Predicting Eelgrass Recovery Under Different Nitrogen-Loading Scenarios

Ecosystems are highly complex and variable systems that can and do change over time in species composition, distribution, and abundance. Scientists working in the waters of Waquoit Bay agree that nitrogen overloading is the major stressor on eelgrass and that decreasing the load of nitrogen to the Bay may result in water quality conditions that could support eelgrass, but there is no certainty that eelgrass will reestablish itself or maintain itself if replanted.

Predicting changes in water quality over time that may result from a decrease in nitrogen loading requires incorporating the travel time of nitrogen in groundwater. With knowledge of the location of houses and groundwater travel times, it is possible to estimate how much nitrogen will be removed under different management scenarios and how much longer the rest of the nitrogen will remain in the aquifer traveling to the Bay. But that information alone is not sufficient to predict the time when water quality conditions would support eelgrass. The contribution of benthic processes and sediment conditions also must be factored into predictions. These parameters increase the uncertainty surrounding the ability to estimate time for recovery.

Output for Examining Model Results and Attendant Management Options

A target load of nitrogen that will lead to water quality conditions that support eelgrass can be identified for specific subembayments or the whole system. Figure 5 illustrates how such a relationship might be portrayed. The probability that eelgrass might cover 10% or less of available habitat is plotted against nitrogen-loading levels to the estuary. If the uncertainty levels in these estimates are high, a curve with a shallow slope results. If uncertainty is low, a closer relationship between eelgrass cover and nitrogen loading exists, and the slope of the curve will be steep. For a 25% probability that eelgrass habitat will be 10% or less of available habitat (or a 75% chance of recovery), required nitrogen loading would be estimated to be much lower under conditions of high uncertainty.

2.3.4 Additional Effects of Other Stressors on Eelgrass

If nitrogen were reduced and eelgrass reestablishes itself or is replanted, other stressors may become important. For example, remaining small stands of eelgrass may be further impacted by natural events (e.g., in 1991, Hurricane Bob overwashed a spit on Washburn Island, burying an eelgrass bed on the inside of Eel Pond). Building docks over eelgrass beds, dredging activities, propeller scour from passing boats, and mooring scars all stress eelgrass.

3. CONCLUSIONS

This document represents only a problem formulation at this time. A more complete ecological risk assessment is forthcoming. For further information on the characterization of risk, see Section 2.3 of this document.

4. RECOMMENDATIONS REGARDING DATA GAPS

4.1 Other Stressors Affect Valued Resources

As funding permits, relationships among other stressors and valued resources will be evaluated.

Physical Alteration of Habitat. The loss of barrier beaches due to insufficient sand transport cannot be addressed in this assessment. Wetlands are an important habitat in the watershed. To date little work has been done on wetlands loss, but as results become available, they will be incorporated into the final risk assessment document if possible.

Altered Flow. The sandy soils of the Waquoit Bay watershed hold copious amounts of water. Future development could affect the quality of groundwater, which has been degraded due to development, and the number of possible well sites. Other potential problems include loss of wetlands function and habitats for trout and alewife spawning due to changes in flow. It is hoped that as more research is conducted, these issues can be addressed.

Toxic Chemicals. A large contingent of scientists and policy-makers are evaluating the problem of toxic plumes emanating from the Superfund site. These stressors may affect the quality of Johns and Ashumet ponds, as well as freshwater and saltwater bodies downgradient. As results become available, the risk assessment team will include their findings in the final Waquoit Bay Ecological Risk Assessment product if possible.

Harvest pressure. Harvesting of fish mainly occurs offshore and is beyond the scope of this assessment. Increased stress on valuable finfish populations comes from degraded estuarine habitats where many offshore fish spawn.

Resuspended Particulates. There is concern that boating, dredging, and shell-fishing activities may resuspend sediments causing harm to valued resources. These issues are under study at Waquoit Bay by the National Estuarine Research Reserve Research Coordinator, Dr. Richard Crawford. Pertinent results will again be added to the risk assessment document if possible.

5. LITERATURE CITATIONS

Collins, G., J. Kremer, and I. Valiela. submitted. Assessing uncertainty in estimates of nitrogen loading to estuaries.

Harris, H. J., R. B. Wenger, V. A. Harris, and D. S. Devault. 1994. A method for assessing environmental risk: a case study of Green Bay, Lake Michigan, USA. Environmental Management 18(2):295-306.

Persky, J. H. 1986. The relation of ground-water quality to housing density, Cape Cod, Massachusetts. Water Resources Investigation Report 86-4093. U.S Geological Survey. Marlborough, MA.

Valiela, I., G. Collins, J. Kremer, K. Lajtha, M. Geist, B. Seely, J. Brawley, and C. H. Sham. 1997. Nitrogen loading from coastal watersheds to receiving estuaries: new method and application. Ecological Applications 7(2):358-380.

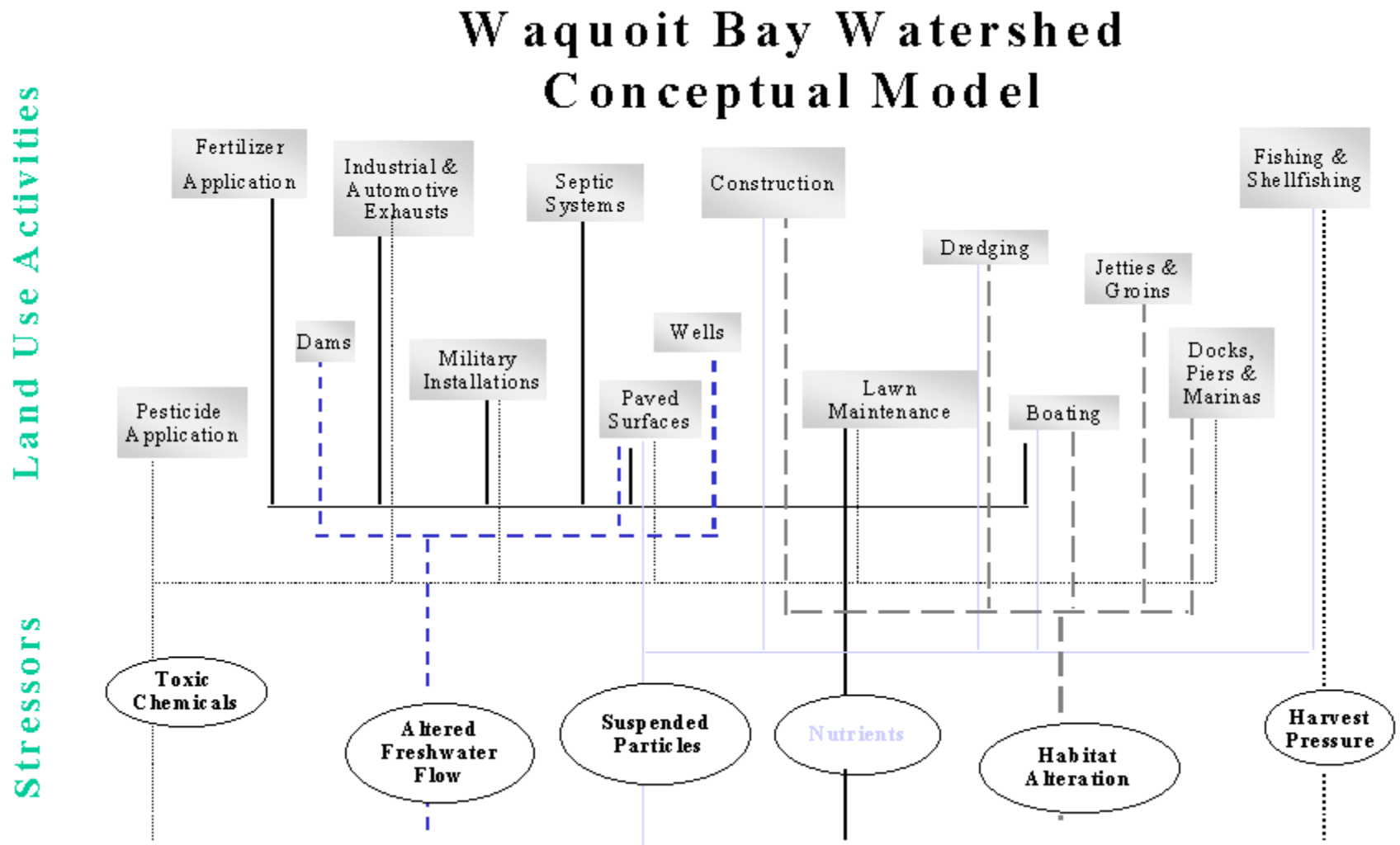

Figure 1a. Conceptual model of the Waquoit Bay watershed ecological risk assessment. This portion shows land use activities and stressors.

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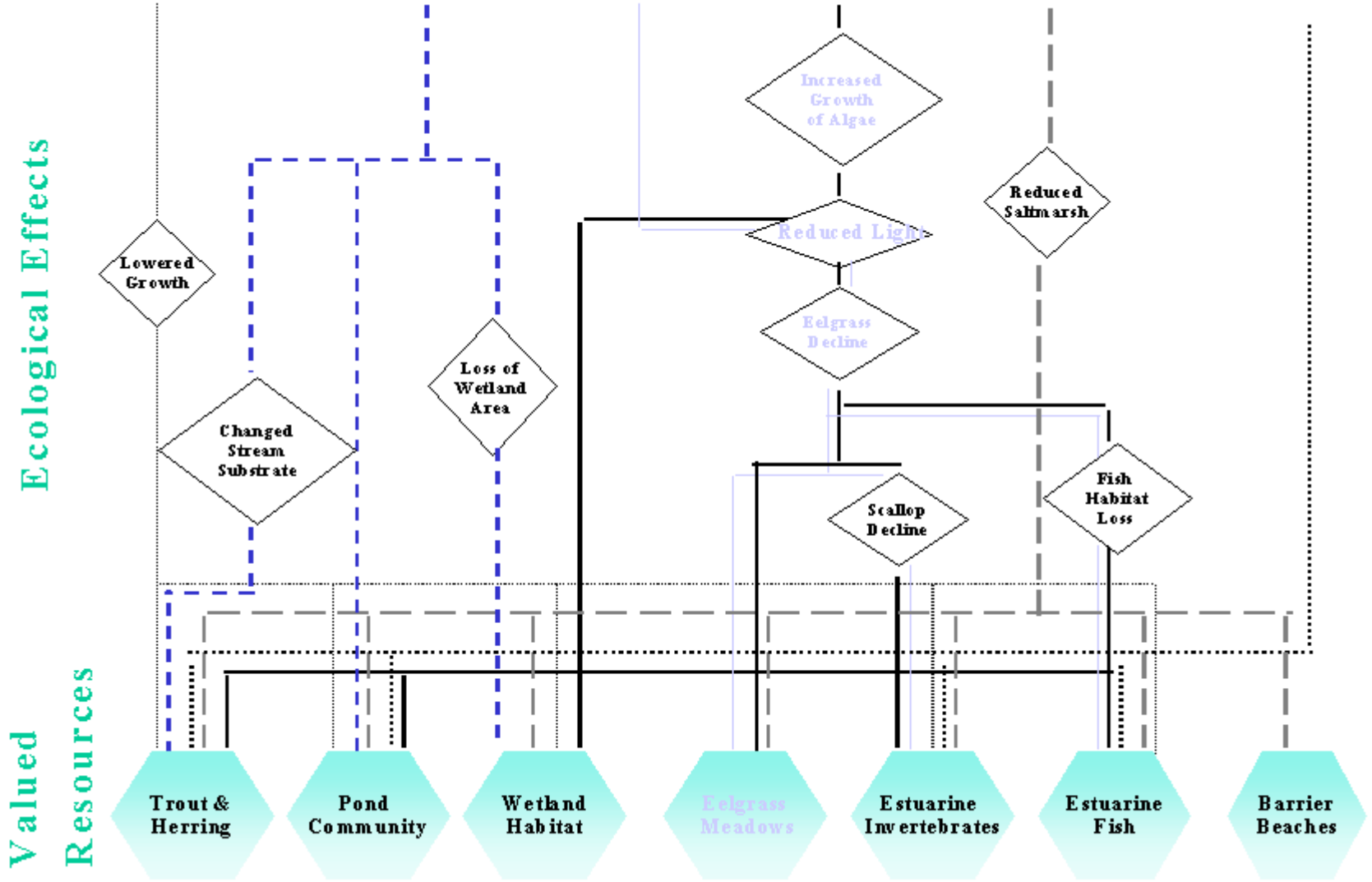

Figure 1b. Conceptual model of the Waqyiut Bay watershed ecological risk assessment. This shows how stressors may interact with the ecological system to cause effects on valued resources.

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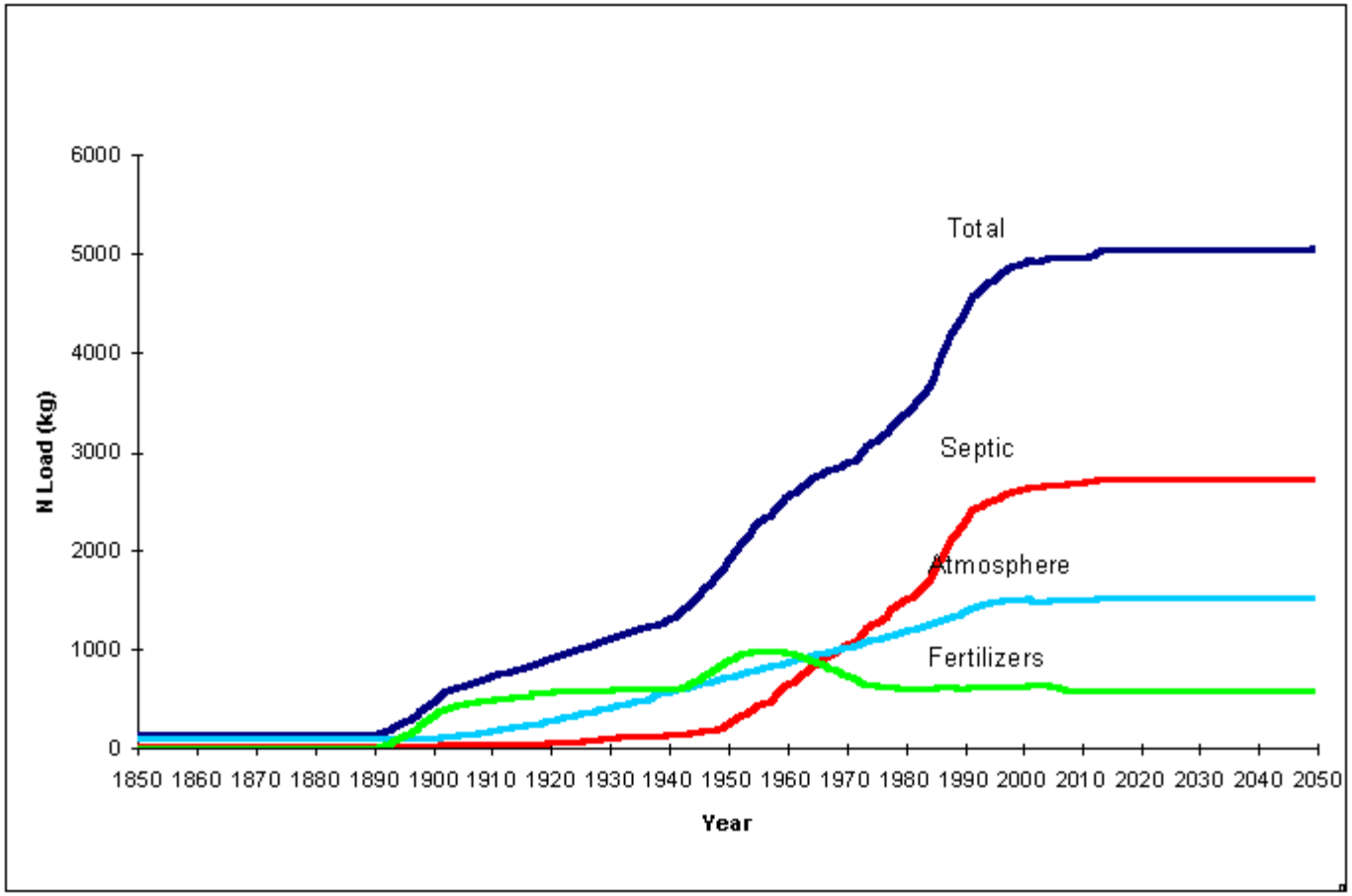

Figure 2. Differences in arrival time of nitrogen between the static and dynamic nitrogen loading models. An example from the Jehu Pond subwatershed of the Waquoit Bay watershed.

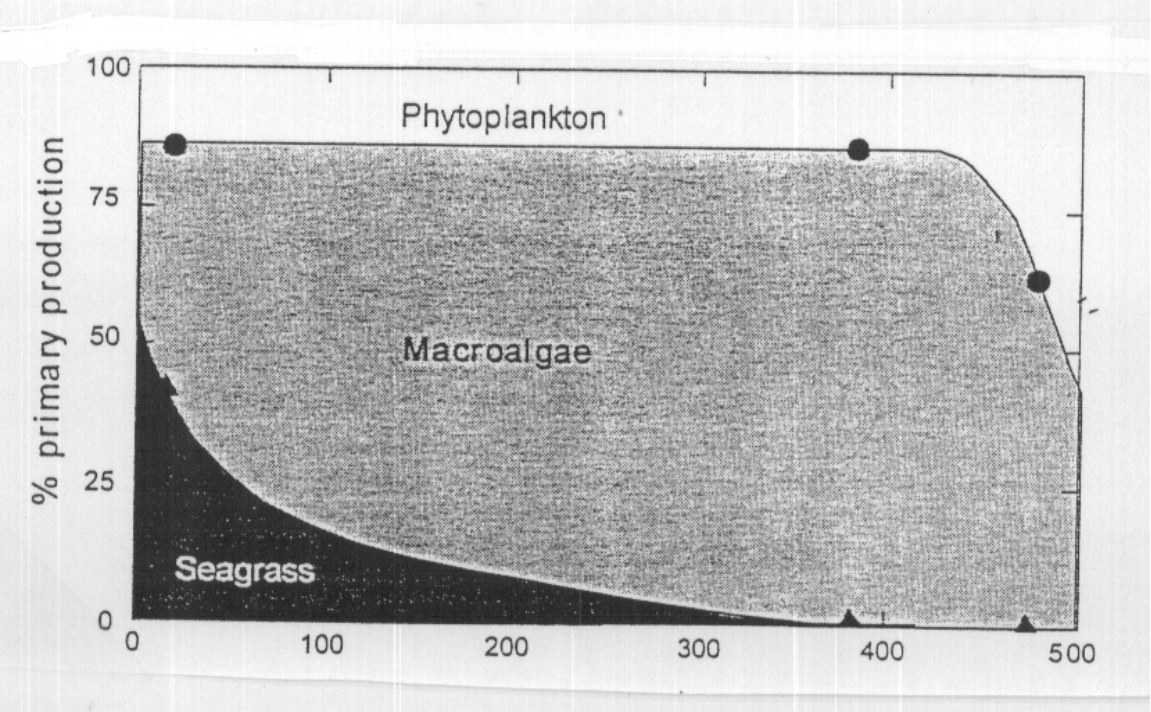

Figure 3. Changes in nitrogen loading alter the relative contribution of primary producers to total production in shallow estuaries (Valiela et al., 1997).

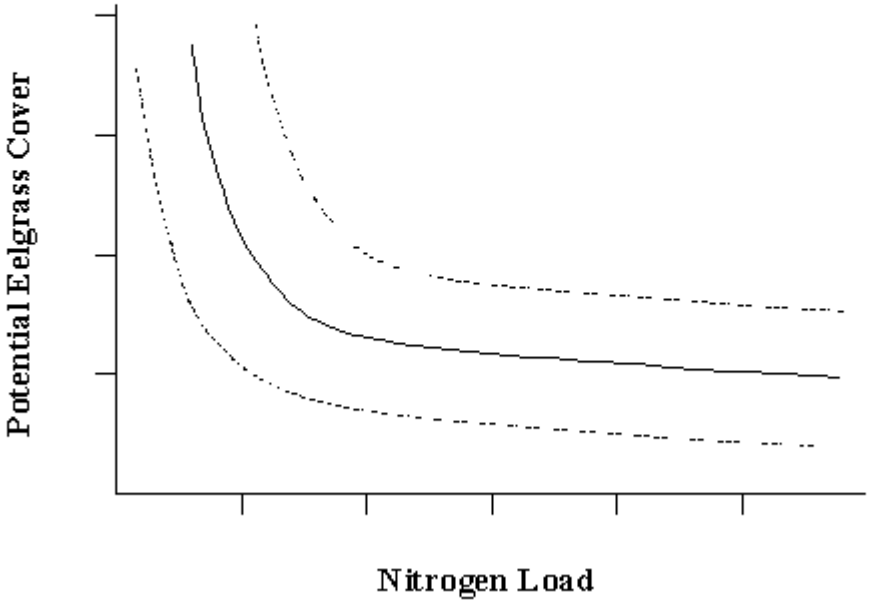

Figure 4. Hypothetical response of eelgrass to increases in nitrogen load.

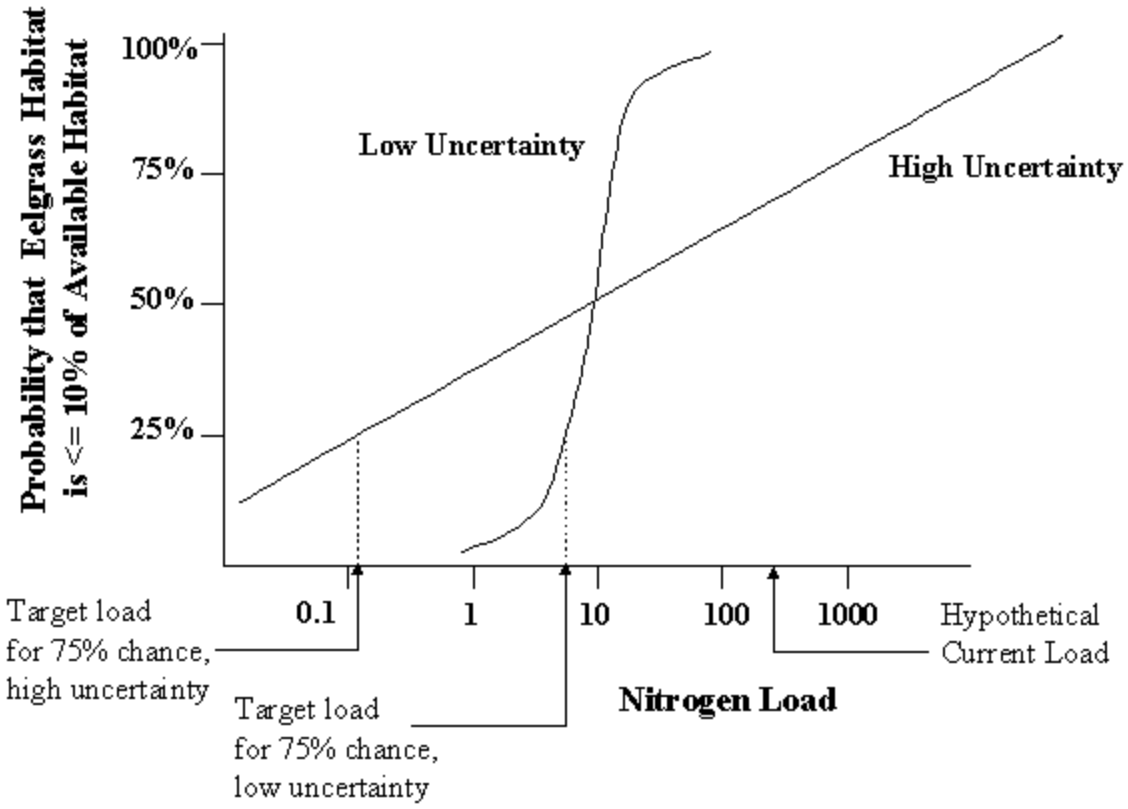

Figure 5. Hypothetical relationship between the probable extent of eelgrass habitat and nitrogen loading under high and low uncertainty (J. Gerritsen, Pers. Com.). See text for explanation.

APPENDIX C

GENERIC KETONE CASE STUDY

Contents

EXECUTIVE SUMMARY . . . . . Page C-3

1. CONTEXT . . . . . Page C-6
   - 1.1 Toxic Release Inventory . . . . . Page C-6
   - 1.2 Scope and Purpose of Generic Ketone Assessment . . . . . Page C-7

2. RISK PARADIGM . . . . . Page C-7
   - 2.1 Hazard Identification . . . . . Page C-7
   - 2.2 Exposure Assessment . . . . . Page C-8
     - 2.2.1 Estimates of Ambient Air Concentrations . . . . . Page C-9
     - 2.2.2 Estimates of Surface Water Concentrations and Drinking Water Consumption . . . . . Page C-10
   - 2.3 Dose-Response, Calculations, and Uncertainties . . . . . Page C-11
     - 2.3.1 MOE Calculations for Ambient Air Concentrations at the Fence Line . . . . . Page C-12
     - 2.3.2 MOE Calculations for Releases to Surface Water . . . . . Page C-14

3. CONCLUSIONS . . . . . Page C-15

4. RECOMMENDATIONS REGARDING DATA GAPS . . . . . Page C-15

5. LITERATURE CITATIONS . . . . . Page C-16

APPENDIX A
HAZARD AND EXPOSURE ASSESSMENTS OF GENERIC KETONE . . . Page C-17

Tables

Table 1. Estimated Ambient Air Concentrations of Generic Ketone For Three Facilities . . . . . Page C-9
Table 2. Estimated Ambient Air Concentrations of Generic Ketone — Impact of Pattern of Release . . . . . Page C-10
Table 3. Acute Exposures Resulting From Surface Water Releases . . . . . Page C-11
Table 4. MOEs for the Average to Worst Case Day of the Year . . . . . Page C-13
Table 5. MOEs for Drinking Water Consumption . . . . . Page C-15

Risk Characterization of Generic Ketone

EXECUTIVE SUMMARY

Context

EPA received a petition to remove generic ketone from the Toxic Release Inventory (TRI). Outside parties may petition EPA to list chemicals that are not currently on the TRI or to delist chemicals from the TRI. Originally, EPA had included generic ketone on the TRI due to concerns about developmental toxicity, neurotoxicity, hepatic toxicity, and renal toxicity. The petitioner stated that new information indicates that the toxicity profile for generic ketone does not meet the criteria for listing on the TRI. In addition, the petitioner stated that the exposure estimates for facilities with the highest reported releases do not support a concern for risk to human health.

The purpose of EPA's screening level risk assessment of generic ketone was to assist EPA senior managers in addressing the delisting petition. EPA has 180 days to respond to a petition and generally conducts a screening level risk assessment, which is not peer reviewed due to the tight timeline. Risk assessors reviewed all available epidemiology and animal toxicology studies of generic ketone to determine whether they met the criteria for listing the chemical on the TRI. Potential ecological effects were not addressed since they had not been the basis of the original listing of generic ketone and no new information is available that would impact the original assessment.

Risk Paradigm

<u>Exposure</u>

EPA considers two scenarios when assessing human exposure to a chemical that is listed on the TRI: (1) ambient air concentration at the fence line of a particular facility, and (2) the concentration in the surface water that feeds into a drinking water facility. Facilities must report only total annual emissions based on actual measurements or estimates of the emissions. As a result, risk assessors had to estimate daily air and water concentrations of generic ketone from a single estimate of the total amount released during the year by each facility. To do this in accordance with EPA's Office of Pollution Prevention and Toxics' policy, they chose a default value of 24 hours per day, 365 days per year to estimate ambient air concentrations and surface water concentrations. The greatest source of uncertainty in estimating these concentrations pertains to the assumption that generic ketone is released continuously over the year.

Risk assessors used the Industrial Source Complex Short Term model to estimate ambient air concentrations of generic ketone at the fence line of three facilities with the highest releases to air (stack and fugitive) in 1994. Meteorological information based on each facility's zip code

was the only site-specific data available to the modelers. All other parameters represented default values, which for the most part were based on conservative assumptions. If releases were to occur over shorter durations than those based on continuous release over the year (the default), the estimated ambient air concentrations, which ranged from 0.25 to 4.8 ppm, could increase up to a factor of 52.

Risk assessors derived estimates of generic ketone in drinking water using the ReachScan model. Because the primary human health concern is potential developmental toxicity, the modelers estimated drinking water consumption rates on a daily basis (referred to as the acute potential dose rate) from surface water concentrations at three facilities with the highest releases to water. If releases of generic ketone were to occur over shorter periods than those estimated using the default of continuous exposure over the year, the estimated surface water concentrations, which ranged from 4.4 to 47 ppb, could increase up to a factor of 37.

Effect

Only the developmental toxicological studies provided sufficient evidence that generic ketone can be reasonably anticipated to cause serious or irreversible health effects. Also, developmental effects represented the only endpoint that was consistent with the criteria for listing a chemical on the TRI. Extensive uncertainty exists about other types of potential health effects (neurological, hepatic, renal, reproductive, and cancer) that were not considered because the data are lacking or do not support a concern that is consistent with the criteria for TRI listing.

Inhalation prenatal developmental toxicity was observed in mice and rats, but maternal toxicity was not observed in either species. Mice exposed to generic ketone exhibited an increased incidence of dead fetuses, reductions in fetal body weight, and delayed ossification. In rats, exposure to generic ketone was associated with reduced fetal body weight and delayed ossification. For both species, the Lowest Observed Adverse Effect Level was 3,000 ppm and the No Observed Adverse Effect Level (NOAEL) was 1,000 ppm. There were no oral developmental toxicity data available for generic ketone. According to the EPA guidelines for developmental toxicity risk assessment (1991), evidence of developmental toxicity in a single animal study is sufficient to assume a potential hazard to humans.

Calculations and Uncertainties

Risk assessors used a margin of exposure (MOE) approach to describe the potential for developmental toxicity associated with exposure to generic ketone. The MOE is calculated as the ratio of the NOAEL for developmental toxicity to the estimated exposure level. Risk assessors applied two uncertainty factors to the calculation, each with a value of 10 in accordance with Agency policy: one for consideration of intraspecies variation and another for interspecies variation.

Overall, the risk assessment supports a low concern for potential developmental effects resulting from releases of generic ketone to surface water or air (stack or fugitive). The MOE estimates for drinking water exposure ranged from 10^6 to 10^7. Because these MOEs are so large, there is a high level of confidence that no appreciable concern exists due to releases to surface water. Although uncertainties associated with the duration of release of generic ketone to water could result in an increase in the surface water concentration by a factor of 37, the estimate would have to increase by a factor of 1,000 to change the MOE enough to influence the level of concern.

The MOE estimates for air exposure at the fenceline are greater than 100 at all three facilities, which according to Agency policy indicates a low level of concern for developmental toxicity resulting from exposure to generic ketone. However, there are substantial uncertainties associated with the pattern and duration of release of generic ketone to ambient air that could result in an increase in the ambient air concentration estimate by a factor of 52. Such an increase would raise the level of concern for developmental toxicity. Given the uncertainties, the policy to view a MOE of 100 as a "bright line" may not be sufficiently conservative in this case since the uncertainty associated with the exposure assessment for ambient air concentrations may be higher than the MOE value of 100.

1. CONTEXT

1.1 Toxic Release Inventory

Under the reporting requirements of Section 313 of the Emergency Planning and Community Right-To-Know Act of 1986 (EPCRA), facilities that use greater than 10,000 pounds or that manufacture or process greater than 25,000 pounds of any chemical on the Toxic Release Inventory (TRI) are required to report their total annual emissions to EPA and the states. The criteria that EPA uses to determine whether a chemical should be on the TRI include consideration of both human health and ecological effects as follows:

a) The chemical is known to cause or can reasonably be anticipated to cause significant adverse acute human health effects at concentration levels that are reasonably likely to exist beyond facility site boundaries as a result of continuous, or frequently recurring, releases;

b) The chemical is known to cause or can reasonably be anticipated to cause in humans cancer or teratogenic effects, or serious or irreversible effects including reproductive dysfunctions, neurological disorders, heritable gene mutations, or other chronic health effects.

c) The chemical is known to cause or can reasonably be anticipated to cause, because of its toxicity, its toxicity and persistence in the environment, or its toxicity and tendency to bioaccumulate in the environment, a significant adverse effect on the environment.

In accordance with Agency science policy, traditionally cancer and heritable gene mutations have been viewed as non-threshold effects, whereas non-cancer effects have been viewed as threshold effects. Accordingly, the analyses required to include a chemical on the TRI differ for heritable gene mutations and cancer versus non-cancer effects. Hazard information that provides evidence that the chemical causes or can be reasonably anticipated to cause heritable gene mutations or cancer in humans is sufficient for a chemical to be included on the TRI. In contrast, for non-cancer effects, the hazard data must first be evaluated and determined to be sufficient to provide evidence that the chemical can reasonably be anticipated to pose a hazard to humans. If the hazard case is determined to be strong enough, then a risk assessment is subsequently conducted to demonstrate that under the specific exposure conditions, the chemical can be reasonably anticipated to cause the effect in humans.

It is possible for outside parties to petition EPA to list chemicals that are not currently included on the TRI or to delist chemicals from the TRI. When a petition is submitted, the Agency has 180 days to respond. Given this timeline, the Agency conducts a screening level

hazard, and, if necessary, a risk assessment of the chemical in question. An external peer review is not conducted for these assessments due to the tight timeline.

1.2 Scope and Purpose of Generic Ketone Assessment

EPA recently received a petition to remove a chemical, referred to in this assessment as generic ketone, from the TRI. Originally, EPA had included generic ketone on the TRI due to concerns for developmental toxicity, neurotoxicity, hepatic toxicity, and renal toxicity. The petitioner stated that new information indicates that the toxicity profile for generic ketone does not meet the criteria for listing on the TRI and that the exposure estimates for facilities with the highest reported releases do not support a concern for risk to human health.

The purpose of the screening level risk assessment of generic ketone is to assist EPA senior managers in addressing the delisting petition. All available epidemiology and animal toxicology studies of generic ketone were reviewed to determine whether they met the above EPCRA criteria for listing. Potential ecological effects were not addressed since they had not been the basis for the original listing of generic ketone and no new information is available that would impact the original assessment. Agency risk assessment guidelines were followed. This document constitutes the risk characterization for the risk assessment. The hazard and exposure portions of the risk assessment are provided in Appendix A.

Two exposure scenarios are considered when assessing human exposure to a chemical that is listed on the TRI. The first scenario is the ambient air concentration at the fence line of a facility, and the second is the concentration in the surface water that feeds into a drinking water facility. Risk assessors used the Industrial Source Complex Short Term model to derive estimates of the ambient air concentrations of generic ketone at the fence line of specific facilities. Estimates of generic ketone in drinking water were derived using the ReachScan model. Agency exposure guidelines were followed for the exposure assessment.

2. RISK PARADIGM

The risk characterization for generic ketone is presented below. It was concluded from the risk assessment that there is low concern for human health effects resulting from exposure to ambient air concentrations of generic ketone at the fence line or from surface water releases of generic ketone.

2.1 Hazard Identification

EPA evaluated the epidemiology and animal toxicology studies to determine the overall toxicological profile of generic ketone and to determine whether sufficient evidence exists to demonstrate that generic ketone can cause or reasonably be anticipated to cause severe or irreversible health effects in humans. In general, there are very limited data available concerning

the potential toxicity of generic ketone. Generic ketone is an eye and respiratory irritant in humans at concentrations of 100-500 ppm, but it has not been associated with significant neurobehavioral effects.

In animal studies, generic ketone has low acute toxicity by the oral, dermal, and inhalation routes. For example, in acute oral toxicity studies, the LD_{50} in rats, mice, and guinea pigs, ranges from 1.9 - 4.6 g/kg. A dermal LD_{50} in the rabbit of >16 g/kg has been reported. In acute inhalation toxicity studies in rats, the LC_{50} ranges from 2,000 to greater than 4,000 ppm.

Subchronic animal studies have provided equivocal evidence of neurotoxicity, hepatic toxicity, and renal toxicity. However, chronic studies were not available, so it was not possible to support or refute the findings from the short-term studies. Similarly, there are no data available regarding the potential reproductive toxicity or carcinogenicity of generic ketone. The results of mutagenic assays indicate that generic ketone has little mutagenic activity.

Inhalation prenatal developmental toxicity studies have been conducted in rats and mice. Developmental toxicity was observed in mice and rats, but maternal toxicity was not observed in either species. In mice, exposure to generic ketone was associated with an increased incidence of dead fetuses, reductions in fetal body weight, and delayed ossification. In rats, exposure to generic ketone was associated with reduced fetal body weight and delayed ossification. For both species, the LOAEL was 3,000 ppm and the NOAEL was 1,000 ppm.

The only toxicological studies that provide sufficient evidence that generic ketone can be reasonably anticipated to cause serious or irreversible health effects are the developmental toxicity studies. According to EPA guidelines for developmental toxicity risk assessment (1991), evidence of developmental toxicity in a single animal study is sufficient to assume a potential hazard to humans. Since this is a non-cancer endpoint, it is necessary to conduct a risk assessment to determine whether there is a potential hazard to humans as specified under EPCRA 313.

There are several sources of uncertainty associated with the hazard assessment. The major uncertainty is due to the paucity of human health effects and toxicological information on generic ketone. Sufficient evidence exists to support a potential concern for developmental effects. However, there is a great deal of uncertainty regarding the potential for other health effects due to a lack of information.

2.2 Exposure Assessment

A summary of the exposure assessments for ambient air and drinking water concentrations is provided below (see Appendix A for details). For human health effects, two exposure scenarios are considered when assessing the exposure to a chemical that is listed on the TRI. The first scenario is the ambient air concentration at the fence line of a particular facility,

and the second is the concentration in the surface water that feeds into a drinking water facility. Facilities that meet the reporting requirements of EPCRA 313 must report to EPA the total annual emissions of the chemical listed on the TRI. The information is supplied simply as the total annual emission and may be based on actual measurements of the emissions or on estimates of the emissions. No information is provided regarding the pattern of the emissions throughout the year. Therefore, for this exposure assessment it was necessary to estimate daily air concentrations and water concentrations of generic ketone from a single estimate of the total amount released during the year by each facility.

Releases reported for generic ketone during 1994 were retrieved from the Toxic Release Inventory System (TRIS) data base. According to TRIS, more than 25,500,000 pounds of generic ketone were released in 1994 from 1,031 sources nationwide. Of this amount, 27 percent was from fugitive or nonpoint source emissions and 72 percent originated from stack or point source emissions to the atmosphere. In addition, lesser amounts of generic ketone (less than 1 percent) were released to surface waters, underground injection of wastes, and the land.

2.2.1 Estimates of Ambient Air Concentrations

The Industrial Source Complex Short Term (ISCST3) model was used to derive estimates of the ambient air concentration of generic ketone at the fence line. For this assessment, modeling was conducted for the three facilities that reported the highest releases of generic ketone in 1994 to air (stack and fugitive). The ISCST3 model was used to calculate estimates of the ambient air concentration for three scenarios, the single worst day (highest concentration) of the year, the 50th worst day of the year, and the average day. Each of these estimates for the three facilities is shown in Table 1.

Table 1. Estimated Ambient Air Concentrations of Generic Ketone For Three Facilities

Facility	Type of Day Modeled	Estimated Ambient Air Concentration (ppm)
A	Highest Concentration Day	4.8
	50th Highest Concentration Day	1.9
	Average Day	0.5
B	Highest Concentration Day	2.3
	50th Highest Concentration Day	1.3
	Average Day	0.3

C	Highest Concentration Day	2.0
	50th Highest Concentration Day	1.2
	Average Day	0.25

There are many uncertainties associated with the estimates shown in Table 1. The impact of different assumptions regarding the pattern of releases of generic ketone on the estimates of the ambient air concentration is shown in Table 2. As noted above, the only site-specific information available was some meteorological information based on the zip code of the facility. All other parameters used in the model were default values, which for the most part are based on conservative assumptions. The largest source of uncertainty is associated with the pattern and duration of the release of generic ketone. The values shown in Table 1 were derived based on the assumption that releases of generic ketone take place continuously over 365 days per year. This assumption is necessary since the only site-specific data available are a single estimate of total annual release; therefore the actual number of days when releases occur is unknown. However, if releases actually occur over shorter periods, the model would estimate higher ambient air concentrations.

Table 2. Estimated Ambient Air Concentrations of Generic Ketone — Impact of Pattern of Release

If Releases Occurred...	Air Concentrations Would Increase By a Factor of...
Over 24 hours/day, but only on weekdays	1.5
Over 24 hours/day every day, but only 6 months/year	2
Over 365 days, but only one 8-hour shift per day	3
Over 24 hours/day every day, but only 1 month/year	12
Over 24 hours/day every day, but only 1 week/year	52

2.2.2 Estimates of Surface Water Concentrations and Drinking Water Consumption

The ReachScan model was used to derive estimates of the surface water concentration of generic ketone resulting from reported releases to surface water. The potential exposure of the population to releases of generic ketone to surface water is through consumption of drinking water. Drinking water consumption can be calculated on a daily basis or as a lifetime average. The former estimate is generally referred to as the acute potential dose rate (APDR), and the latter is generally referred to as the lifetime average daily dose (LADD). The APDR is

calculated when the toxic effect of a chemical is thought to be the result of a short-term acute exposure, whereas the LADD is calculated when the toxic effect is thought to be the result of long-term chronic exposure. For generic ketone, the primary concern is for potential developmental toxicity. A central assumption in developmental toxicity risk assessment is that developmental effects can result from a single exposure to the chemical (EPA 1991). Therefore, for this assessment, it is most appropriate to use estimates of the APDR.

The three facilities with the highest annual releases to surface water were modeled by ReachScan for this assessment. The estimated surface water concentrations and the associated drinking water APDRs are presented in Table 3. The generic ketone concentrations in the water range from 4.4 to 47 μg/L at the three highest drinking water utilities. The drinking water APDRs range from 1.4×10^{-4} to 1.4×10^{-3} mg/kg/day.

Table 3. Acute Exposures Resulting From Surface Water Releases

Facility	Estimated Surface Water Concentration (μg/L)	Acute Potential Dose Rate (mg/kg/day)
1	47	0.0014
2	9	0.00028
3	4.4	0.00014

There are several sources of uncertainty associated with the estimates of surface water concentration and the resultant estimates of APDR. The greatest source of uncertainty pertains to the assumption that generic ketone is released continuously over 365 days per year. However, if releases actually occur over shorter periods, the model would estimate higher surface water concentrations. For example, if the releases occurred over 10 days per year the value calculated for the surface water concentration would increase by a factor of 37. The value would increase by a factor of 12 or 1.5 if releases occurred over 30 days per year or 250 days per year, respectively. The resultant APDRs would increase by the same amount.

2.3 Dose-Response, Calculations, and Uncertainties

This assessment focuses on the potential risk of developmental toxicity associated with exposure to generic ketone. Developmental effects are considered in the analysis because they represent the only endpoint for which the hazard data were consistent with the criteria specified by EPCRA 313. Other types of health effects are not considered either because the available data do not support a concern that is consistent with the criteria, or the data are lacking.

A margin of exposure (MOE) approach is used in this assessment to describe the potential for developmental toxicity associated with exposure to generic ketone. The MOE is calculated

as the ratio of the NOAEL for developmental toxicity to the estimated exposure level. The MOE does not provide an estimate of population risk; it simply describes the relative distance between the exposure level and the NOAEL. The value of the MOE that is associated with a concern for toxic effects is generally expressed as the product of the applicable uncertainty and modifying factors. Uncertainty factors that the Agency considers for non-cancer effects are described in IRIS (1998). For consideration of developmental toxicity, the applicable uncertainty factors are described in the developmental toxicity risk assessment guidelines (EPA 1991). These include two uncertainty factors, one for consideration of intraspecies variation and another for interspecies variation. In accordance with Agency science policy, each of these uncertainty factors is given a value of 10. Thus, for developmental effects, an MOE greater than 100 would generally indicate a low level of concern, whereas a value less than 100 is judged to be of concern.

As described previously, inhalation developmental toxicity studies of generic ketone have been conducted in mice and rats. No maternal toxicity was noted in either study. Similar developmental effects were noted in both species, and included reduced fetal body weight, delayed ossification, and increased fetal death (mice only). For both species, the LOAEL was 3,000 ppm and the NOAEL was 1,000 ppm. In accordance with Agency science policy regarding developmental toxicity studies, the LOAEL's and NOAEL's were not duration-adjusted (EPA 1991). In addition, human equivalent concentrations were not calculated since a blood:air partition coefficient was not available for generic ketone. Although the RfC guidance (EPA 1994) suggests that a default value of 1 can be used in the absence of a blood:air partition coefficient, this results in a less conservative risk assessment. In such cases, it is OPPT policy to use the more conservative approach. Therefore, for this assessment the NOAEL of 1,000 ppm was used in the derivation of the MOE. Separate analyses were conducted for the two exposure scenarios. Each is presented below.

2.3.1 MOE Calculations for Ambient Air Concentrations at the Fence Line

To determine the MOEs for exposure at the fence line of the three facilities with the highest releases of generic ketone, the NOAEL of 1,000 ppm was divided by the estimated ambient air concentrations (Table 1). MOEs were calculated for three exposure scenarios at each facility: the day with the highest ambient air concentration of generic ketone, the 50th highest day of the year, and the average day of the year. These values are shown below in Table 4. The MOEs are greater than 100 under all three exposure conditions at each facility, which in accordance with Agency science policy would indicate a low level of concern for developmental toxicity resulting from exposure to generic ketone at the fence line.

There are several sources of uncertainty associated with the hazard/dose response assessment and the exposure assessment that impact the specific MOEs. The hazard assessment was conducted in accordance with the criteria used to assess whether a chemical should be on the TRI. Thus, the hazard data were assessed within a framework of whether the data are sufficient

to determine with reasonable certainty that serious or irreversible effects are likely to occur in humans. There was some equivocal evidence of neurotoxicity, hepatic toxicity, and renal toxicity from short-term animal studies; however, chronic toxicity studies were not available so it was not possible to provide evidence to support or refute the findings from the short-term studies. Similarly, there were no data available regarding the potential reproductive toxicity or carcinogenicity of generic ketone. Thus, while the toxicologic data for effects other than developmental effects were not strong enough for the purposes of EPCRA, there is uncertainty regarding the potential for other types of effects resulting from exposure to generic ketone.

Table 4. MOEs for the Average to Worst Case Day of the Year

Facility	Type of Day Modeled	MOE
A	Highest Concentration Day	209
	50th Highest Concentration Day	530
	Average Day	1,944
B	Highest Concentration Day	430
	50th Highest Concentration Day	785
	Average Day	3,710
C	Highest Concentration Day	510
	50th Highest Concentration Day	833
	Average Day	4,082

A second source of uncertainty in the hazard/dose-response assessment is the use of a NOAEL from a rodent study in the calculation of the MOE. The Agency has developed guidance for dosimetric conversions of animal inhalation concentrations to human equivalent concentrations. Unfortunately, for a compound such as generic ketone, such conversions require knowledge of the blood:air partition coefficient. This was not available for generic ketone, and therefore derivation of a human equivalent concentration was not feasible. The impact of this on the MOE is not known.

There are also many uncertainties associated with the exposure assessment. As noted previously, the only available information on actual releases of generic ketone are total annual releases from the facilities. Therefore, ambient air concentrations are derived through the use of the ISCST3 model. This model requires the input of various parameters, and in the absence of site-specific information, default values are used. The only site-specific information that was available in this case was some meteorological data obtained using the zip codes of the facilities.

For the default values, the largest source of uncertainty exists for the number of hours per day and number of days per year that generic ketone was actually released from each facility. In accordance with OPPT policy, a default value of 24 hours per day, 365 days per year was used to calculate the ambient air concentrations. These estimates can increase up to a factor of 52 when releases are estimated over shorter durations (Table 2).

If it were assumed that releases occurred only 8 hours per day (one work shift), 365 days per year, the estimates of ambient air concentrations would increase by a factor of 3. This would result in estimates ranging from 14.4 ppm (facility A, highest concentration day) to 0.75 ppm (facility C, average day). The resulting MOEs would then range from 70 (facility A, highest concentration day) to 1,333 (facility C, average day). This would not change the level of concern for facilities B or C but would indicate a higher level of concern for facility A for the worst case day. If it was assumed that generic ketone was released 24 hours per day, but only for 1 week per year the estimates of ambient air concentrations would increase by a factor of 52. The estimates would then range from 13 ppm (facility C, average day) to 250 ppm (facility A, highest concentration day). Increasing the ambient air concentrations by a factor of 52 would result in MOEs ranging from 4 (facility A, highest concentration day) to 77 (facility C, average day). In accordance with Agency policy, MOEs in this range would suggest that there is a relatively high concern for potential developmental effects.

2.3.2 MOE Calculations for Releases to Surface Water

The potential exposure of the population to releases of generic ketone to surface water would be through consumption of drinking water. Ideally, a NOAEL from an oral study would be used for the derivation of MOEs in this exposure since this is the route of concern. However, there are no oral developmental toxicity data available for generic ketone. Therefore, to determine the MOEs for exposure from drinking water, it was necessary to assume that the inhalation developmental toxicity data were relevant for oral exposures (EPA 1991). Accordingly, the NOAEL of 1,000 ppm was converted to units of mg/kg/day.[1]

MOEs were then derived by dividing the NOAEL in mg/kg/day by the estimated acute potential dose rate (APDR) (shown in Table 3); these are presented in Table 5. The APDR estimates resulting from surface water releases for the top three discharging facilities range from 2.8×10^{-5} - 1.4×10^{-3} mg/kg/day. Using the rat NOAEL, the MOE values for these estimates range from 3.3×10^{7} - 3.3×10^{7}. Using the mouse NOAEL, the MOE values for these estimates range from 2.3×10^{7} - 4.6×10^{6}.

[1] [ppm X (molecular weight/24.5) X rodent ventilation rate (m^3/day)]/ rodent body weight = mg/kg/day. For the rat, this becomes: [1,000 ppm X (100/24.5) X 0.14 m^3/day]/ 0.124 kg = 4,608 mg/kg/day. For the mouse, this becomes: [1,000 ppm X (100/24.5) X 0.04 m^3/day]/ 0.025 kg = 6,531 mg/kg/day.

Table 5. MOEs for Drinking Water Consumption

Facility	MOE (using rat NOAEL)	MOE (using mouse NOAEL)
1	3.3×10^6	4.6×10^6
2	1.6×10^7	2.3×10^7
3	3.3×10^7	4.6×10^7

There are uncertainties associated with the assessment that could influence the calculated MOEs. The largest source of uncertainty in the exposure assessment is the default value used for the number of hours per day and number of days per year that generic ketone was actually released from the facilities. A default value of 24 hours per day, 365 days per year was used to calculate the surface water concentrations. These estimates can increase up to a factor of 37 when releases are estimated over shorter durations. However, because the MOEs that are calculated for drinking water are so large, increasing the APDR by a factor of 37 would not alter the level of concern; the ADPR would have to increase by close to a factor of 1,000 to have any appreciable effect on the level of concern for developmental effects. Therefore, even though there is a great deal of uncertainty associated with the drinking water exposure, the MOE is so large that there is a high level of confidence that there is no appreciable concern for developmental effects resulting from exposure to generic ketone released to surface water.

3. CONCLUSIONS

Overall, the assessment supports a low concern for potential developmental effects resulting from releases of generic ketone to air (stack or fugitive) or surface water. There are substantial uncertainties associated with the exposure assessments that could result in increases in the estimates of ambient air concentrations by a factor of 52 and increase estimates of surface water concentrations by a factor of 37. Such an increase would not affect the level of concern for releases to surface water since these estimates would have to increase by a factor of 1,000 to change the MOE enough to effect the level of concern. Increasing the estimates of the ambient air concentration by a factor of 52 may increase the level of concern for developmental toxicity. Given these uncertainties, it may be prudent to point out that the policy to view a MOE of 100 as a "bright line" may not be sufficiently conservative in this case since the uncertainty associated with the exposure assessment for ambient air concentrations may be higher than the MOE value of 100.

4. RECOMMENDATIONS REGARDING DATA GAPS

Several uncertainties that have been highlighted in this assessment could be reduced with additional information. With respect to the toxicological data base, there was equivocal evidence

of neurotoxicity, hepatic toxicity, and renal toxicity from the subchronic studies. If chronic studies were conducted, it would be possible to support or refute these findings. With respect to the exposure data base, there are substantial uncertainties associated with the pattern and duration of the releases of generic ketone to air. These uncertainties could be reduced through the development of accurate release information.

5. LITERATURE CITATIONS

EPA. 1991. Guidelines for developmental toxicity risk assessment. U.S. Environmental Protection Agency. *Federal Register* 56(234): 63798-63826.

EPA. 1994. Methods for derivation of inhalation reference concentrations and application of inhalation dosimetry. U.S. Environmental Protection Agency. EPA/600/8-90/066F.

APPENDIX A
HAZARD AND EXPOSURE ASSESSMENTS OF GENERIC KETONE

1. HAZARD SUMMARY

1.1 Absorption and Metabolism

Absorption and metabolism studies in animals suggest that generic ketone is well-absorbed from the lung, gastrointestinal tract, and skin; well distributed; and rapidly metabolized. Although no metabolism studies have been conducted in humans, short-term exposure to generic ketone is associated with eye and respiratory irritation and clinical signs of reversible central nervous system (CNS) effects. This finding is consistent with the animal studies that demonstrate that generic ketone is rapidly absorbed.

1.2 Acute Toxicity

Available data indicate that generic ketone is associated with low toxicity in humans and animals following acute exposures. In humans, short-term inhalation exposures of up to 30 minutes each day to concentrations as high as 500 ppm produced irritation of the eyes and upper and lower respiratory system—effects characteristic of solvent exposure. In some studies, reversible CNS and irritant effects were seen after 8-hour exposures to 100 ppm, while in other studies, 100 ppm produced no effects (additional studies are described in Section 1.8 of this appendix).

In acute inhalation toxicity studies, rats were able to tolerate concentrations of 2,000 - 4,000 ppm for periods up to 6 hours, while concentrations > 20,000 ppm produced death in all animals within an hour. The estimated 4- and 6-hour LC_{50} in rats were 3,000 and > 4,000 ppm, respectively. Although no mortality was reported in mice exposed to concentrations as high as 900 ppm generic ketone, a decrease in the duration of immobility in a behavioral despair swimming test and a reduction in the respiratory rate were observed. In acute oral toxicity tests, the LD_{50} ranged from 1,900 - 3,000 mg/kg in the mouse and 3,000 - 4,600 mg/kg in the rat. The dermal LD_{50} in rabbits has been reported as being greater than 16 g/kg.

1.3 Mutagenicity

In general, generic ketone does not appear to be associated with genotoxicity *in vitro* or *in vivo*. Generic ketone is not a gene mutagen in *Salmonella typhimurium* strains TA98, TA100, TA1535, and TA1538 either with or without metabolic activation. It is weakly positive in L5178Y $TK^{+/-}$ mouse lymphoma cells *in vitro* without, but not with activation. It is not a chromosome mutagen *in vitro* in Chinese hamster ovary (CHO) and rat RL4 cells, nor does it induce micronuclei *in vivo* in the mouse micronucleus assay by the intraperitoneal injection route. Generic ketone does not induce DNA effects in the *Saccharomyces cerevisiae*

homozygosis and recombination assay, and it is equivocal in the unscheduled DNA synthesis (UDS) assay in rat hepatocytes *in vitro*. It induces morphological cell transformation in BALB/c 3T3 cells in culture without and possibly with metabolic activation.

1.4 Carcinogenicity

There are no human or animal carcinogenicity data on generic ketone.

1.5 Systemic Toxicity from Repeated Doses

Only one epidemiological worker study and a follow-up study are available on the potential effects of generic ketone in humans. However, no information was provided concerning the exposure of the individuals, and potential confounders were not accounted for. As a result, no definitive conclusions could be made.

Limited animal data are available regarding the potential systemic toxicity of generic ketone. A 90-day inhalation toxicity study in rats and mice has been conducted. In that study, 14 male and 14 female Fischer 344 rats and B6C3F1 mice per group were exposed to 0; 50; 250; and 1,000 ppm generic ketone by vapor inhalation 6 hr/day, 5 days/week for 14 weeks. Parameters assessed for toxicity included clinical observations, body and organ weight data, water consumption, urinalysis, serum chemistry, hematology, gross pathology, and histology. No treatment-related effects were noted in the mouse study. In the rat study there was evidence of hepatic toxicity as demonstrated by a dose-related increase in serum cholesterol levels in male rats exposed to 250 and 1,000 ppm (23% and 35% higher than controls, respectively). In addition, there was evidence of renal toxicity; statistically significant dose-related increases in urine glucose excretion occurred in male rats (55%, 37%, and 23% for the 1,000; 250; and 50 ppm levels, respectively) and in female rats at 1,000 ppm (28% above control values). In addition, increases in total urinary protein were observed. The authors of the study suggested that the urinary glucose and protein excretion may be due to functional impairment of normal reabsorption in the renal proximal convoluted tubules. Increases in renal hyaline droplets were also noted in mid- and high-dose male rats. Although the presence of hyaline droplets in the renal proximal tubules may be considered male-rat specific and could explain the functional impairment of glucose and protein absorption in the kidney tubules, increased urinary glucose was observed at the high dose in both sexes. Significant alterations in other parameters of renal function did not occur.

Another group of investigators conducted a 90-day inhalation toxicity study in dogs, rats, and monkeys. They exposed 8 beagle dogs, 100 Wistar rats, and 2 monkeys continuously for 90 days under space cabin conditions (reduced atmospheric pressure) to 100 ppm generic ketone. Dogs and monkeys did not appear to have any toxic responses to the exposure. Special staining of dog kidney sections did not reveal treatment-related effects. Since only 2 monkeys were used per group, the etiology of the chronic inflammation of the kidney in one of the exposed monkeys

is uncertain. Renal toxicity was clearly present in the rats as demonstrated by hyaline droplet nephrosis. The lesions developed within two weeks of exposure and were reversible after 90 days of exposure.

In addition, a subchronic oral toxicity study in rats has been conducted. In that study, four groups of an unspecified number of Sprague-Dawley rats were given 0; 50; 250; and 1,000 mg/kg/day generic ketone by oral gavage daily for 90 days. Doses of 250 mg/kg/day produced increased kidney weights and urinary ketones in both sexes and epithelial cells in males. There were no treatment-related effects at 50 mg/kg/day.

In summary, the major target organs in both the 90-day rat subchronic inhalation and oral toxicity studies were the liver and kidney. Oral gavage doses produced more severe reactions as demonstrated by the changes in clinical chemistry parameters indicative of hepatic toxicity, urinalyses, and histopathological changes in the male rat kidney. The main effects in the inhalation study appeared to be due to functional changes in the liver and kidney, increased liver weight, increased serum cholesterol, and impaired renal absorption of protein and glucose in male rats. However, the elevations in serum chemistry parameters were slight and the liver and kidney effects in the inhalation study were considered to be relatively minor with no major signs of histopathological lesions with the exception of increases in renal hyaline droplets in mid- and high-dose males.

1.6 Developmental Toxicity

Inhalation prenatal toxicity studies have been conducted in rats and mice. In that study, 30 pregnant CD-1 mice and 35 pregnant Fischer 344 rats per group were exposed to 0; 300; 1,000; and 3,000 ppm generic ketone by vapor inhalation 6 hr/day on gestation days (GD) 6-15. In mice, there was no evidence of maternal toxicity. There was evidence of developmental toxicity as demonstrated by an increased incidence of dead fetuses; reductions in fetal body weights per litter; and delayed ossification, which was observed at the high dose of 3,000 ppm. No effects were noted at 1,000 or 300 ppm.

In rats, there was no evidence of maternal toxicity. Exposure to 3,000 ppm resulted in a reduction in fetal body weight per litter and delayed skeletal ossification. Additionally, at 300 ppm but not at 1,000 ppm, there was evidence of reduced fetal body weights per litter and an increase in delayed ossification. The authors of the study reported that historical control data from their laboratory for Fischer 344 rats indicate an inverse relationship between litter size and fetal body weight. They offered this as an explanation for the decreases in fetal body weight observed at the low dose group of 300 ppm. Fetal body weight per litter was examined by dose and by litter size and evaluated statistically. Their analysis indicated that fetal body weights differed significantly from controls for both small and large litters at 3,000 ppm, indicating a treatment-related effect. Conversely, fetal body weights at the 1,000 ppm dose group were comparable to controls for both large and small litters. At 300 ppm, fetal body weights for small,

but not large, litters were significantly reduced compared to controls. The authors contend that the significant reduction in fetal body weight per litter seen in small litters at 300 ppm was actually an artifact of exceptionally heavy fetuses in two small litters in the control group and therefore not treatment-related. Furthermore, the authors argued that since the control group overall had more smaller litters than the 300 ppm group, the evidence of minimal delayed ossification at 300 ppm was consistent with larger litter sizes, concomitant lower fetal body weights, and reductions in ossification. Thus, these effects are not considered to be treatment-related.

In conclusion, adverse developmental effects were noted in the mouse and rat studies; maternal toxicity was not observed in either species. For both species, the NOAEL for maternal toxicity was 3,000 ppm; the LOAEL for developmental toxicity was 3,000 ppm and the NOAEL was 1,000 ppm.

1.7 Reproductive Toxicity

No reproductive/fertility studies have been conducted with generic ketone. The only information available is from the 90 day inhalation toxicity study in mice and rats described above. In that study, organ weight and histological data in high-dose rats and mice were comparable to controls for the ovaries, uterus, oviducts, vagina, cervix, testis, epididymis, prostate, and seminal vesicles. However, this is not sufficient information to characterize the potential for reproductive toxicity of generic ketone.

1.8 Neurotoxicity

Several human studies have examined the neurotoxicity of generic ketone. Although the data are limited to studies with small numbers of subjects, the results are fairly consistent. One group of investigators tested neurobehavioral performance following a 4-hour exposure to 100 ppm generic ketone. Five different psychomotor tests, chemical measurements, and reports of sensory and irritant effects were measured. No marked neurobehavioral effects were reported, but sensory and irritant effects (i.e., odor, headache, nausea, throat irritation, tearing) were reported by 20-30% of the subjects exposed to generic ketone. In another study, 8 subjects were exposed to 50 ppm generic ketone for shorter exposure periods. There were no significant effects on simple reaction time or mental arithmetic tasks. However, irritation of the nose, throat, headache, and vertigo were reported by up to a third of the subjects (based on a questionnaire). Subjects reported an increase in the degree of irritative and CNS symptoms for exposures of 24 ppm and 48 ppm, as compared to 2.4 ppm. Similar results were also reported for 2-hour exposures to 2.4 and 48 ppm generic ketone where subjects reported fatigue and irritation to airways, but no reduction of reaction time or performance on arithmetic tests.

Numerous studies have been conducted in animals to assess the neurotoxic potential of generic ketone. Generally have found no evidence of permanent impairment of neurological

function. For example, histological examination of the nervous system including the brain, spinal cord, and peripheral nerves, was unremarkable, and no clinical signs of neurotoxicity were observed in rats or mice exposed to doses as high as 1,000 ppm generic ketone by vapor inhalation for 90 days.

A 90-day inhalation study of schedule-controlled operant behavior (SCOB) in rats has also been conducted. In this study, male rats were subjected to exposures of 0; 250; 750; and 1,500 ppm generic ketone for 6 hr/day. The results showed that rats exposed to 1,500 ppm exhibited reduced activity and sialorrhea (excessive salivation) following one hour of exposure. This effect was transient, and did not persist after ten weeks of exposure. The same effect was seen in animals exposed to 750 ppm, following 2 hours of exposure, but was only seen during weeks 1 through 8. No effects were seen during exposure to 250 ppm. No significant behavioral effects were detected following exposure at any of the doses tested, using the schedule-controlled operant behavior test. These data indicate that generic ketone may cause transient neurologic effects.

In summary, the available human data are consistent with data previously summarized. Exposure to generic ketone is associated with eye and respiratory irritation at high concentrations, but no human or animal data demonstrate an association between exposure to generic ketone and serious and irreversible neurological effects.

1.9 Hazard Characterization

Human studies have reported irritation of the eyes and mucous membranes as well as symptoms, such as headache, nausea, and vertigo (effects characteristic of solvent exposure) due to inhalation of generic ketone at concentrations ranging from 100 to 500 ppm. However, no significant neurobehavioral effects have been reported at these concentrations.

In animal studies, generic ketone has low acute toxicity by the oral, dermal, and inhalation routes. For example, in acute oral toxicity studies, the LD_{50} in rats, mice, and guinea pigs ranges from 1.9 - 4.6 g/kg. A dermal LD_{50} in the rabbit of >16 g/kg has been reported. In acute inhalation toxicity studies in rats, the LC_{50} ranges from 2,000 to greater than 4,000 ppm.

The results of mutagenic assays indicate that generic ketone has little mutagenic activity. There is neither human nor animal data on the potential carcinogenicity of generic ketone. Subchronic inhalation studies in rats, mice, dogs, and monkeys exposed to concentrations ranging from 50-2,000 ppm generic ketone indicate liver and kidney toxicity. However, in the absence of appropriate chronic data, the data were considered inadequate to support a concern for serious or irreversible effects. Neurotoxicity studies in rats on generic ketone indicate that transient CNS depression can occur at high exposure levels. However, there is no evidence to support a concern for serious or irreversible neurological effects. No conclusions regarding the

potential for reproductive toxicity can be made since no reproductive/fertility studies on generic ketone have been conducted.

Inhalation developmental toxicity studies in rats and mice demonstrate that generic ketone is not associated with maternal toxicity. Developmental toxicity was observed in mice and rats. In mice, exposure to generic ketone was associated with an increased incidence of dead fetuses, reductions in fetal body weight, and delayed ossification. In rats, exposure to generic ketone was associated with reduced fetal body weight and delayed ossification. For both species, the LOAEL was 3,000 ppm and the NOAEL was 1,000 ppm. According to EPA guidelines for developmental toxicity risk assessment (1991), evidence of developmental toxicity in a single animal study is sufficient to assume a potential hazard to humans.

2. EXPOSURE SUMMARY

For human health effects, two exposure scenarios are considered when assessing exposure to a chemical that is listed on the TRI. The first scenario is the ambient air concentration at the fence line of a particular facility, and the second is the concentration in the surface water that feeds into a drinking water facility. As noted previously, facilities that meet the reporting requirements of EPCRA 313 must report the total annual emissions of the chemical listed on the TRI to EPA. The information is supplied simply as the total annual emission and may be based on actual measurements of the emissions or on estimates of the emissions. No information is provided regarding the pattern of the emissions throughout the year. Therefore, for this exposure assessment it was necessary to estimate daily air concentrations and water concentrations of generic ketone from a single estimate of the total amount released during the year by each facility.

Releases reported for generic ketone during 1994 were retrieved from the Toxic Release Inventory System (TRIS) data base. According to TRIS, more than 25,500,000 pounds of generic ketone were released in 1994 from 1,031 sources nationwide. Of this amount, 27 percent was from fugitive or nonpoint source emissions and 72 percent originated from stack or point source emissions to the atmosphere. In addition, lesser amounts of generic ketone (less than 1 percent) were released to surface waters, underground injection of wastes, and the land.

The Industrial Source Complex Short Term (ISCST3) model was used to derive estimates of the ambient air concentration of generic ketone at the fence line. For this assessment, modeling was conducted for the three facilities that reported the highest releases of generic ketone in 1994 to air (stack and fugitive). The ReachScan model was used to derive estimates of the surface water concentration of generic ketone. This information was then used to calculate general population exposures resulting from surface water releases to drinking water sources. A description of the ISCST3 and the ReachScan models is provided below.

2.1 Modeling Ambient Air Concentrations of Generic Ketone

The ISCST3 model was used to estimate short-term ambient air concentrations. The model requires the input of certain information, such as pollutant emission rate; stack height (for point sources); release height (for area sources); stack gas temperature; stack diameter; stack gas exit velocity; location of the point of emission with respect to surrounding topography and the character of that topography; a detailed description of all structures in the vicinity of the stack in question; and similar information from other significant sources in the vicinity of the subject source stack height. Ideally, the input for these parameters would be based on site-specific data. However, in the absence of site-specific information generic default values are used.

For generic ketone, the only site-specific information available was some meteorological data. By using the zip code or the latitude and longitude of the release site, the ISCST3 model can access meteorological data (e.g., wind speed and direction) from the nearest weather station. If several stations are nearby, the user selects the one that he or she believes adequately portrays the release site. The following generic parameters were used for the three facilities:

STACK PARAMETERS	**ASSUMPTIONS**
Duration of releases:	24 hours
Release height:	10 meters
Inner stack diameter:	0.01 meters
Exit gas temperature:	293°K
Exit gas velocity:	0.01 meters/sec
Distance to fence line:	100 meters
Site layout:	flat, rural
Generic ketone half life:	164,160 seconds (1.9 days)
Other modeling options:	default

FUGITIVE (AREA) PARAMETERS	**ASSUMPTIONS**
Duration of releases:	24 hours
Release height:	3 meters
Exit gas temperature:	293°K
Area source size:	10m by 10m
Exit gas velocity:	0.01 meters/sec
Distance to fence line:	100 meters
Site layout:	flat, rural
Generic ketone half life:	164,160 seconds (1.9 days)
Other modeling options:	default

The ISCST3 model was used to calculate estimates of the ambient air concentration for three scenarios, the single worst day (highest concentration) of the year, the 50th worst day of the year and the average day. Each of these estimates for the three facilities is shown in Table 1.

Table 1. Estimated Ambient Air Concentrations of Generic Ketone For Three Facilities

Facility	Type of Day Modeled	Estimated Ambient Air Concentration (ppm)
A	Highest Concentration Day	4.8
	50th Highest Concentration Day	1.9
	Average Day	0.5
B	Highest Concentration Day	2.3
	50th Highest Concentration Day	1.3
	Average Day	0.3
C	Highest Concentration Day	2.0
	50th Highest Concentration Day	1.2
	Average Day	0.25

There are many uncertainties associated with the estimates shown in Table 1. As noted above, the only site-specific information available was some meteorological information based on the zip code of the facility. All other parameters used in the model were default values, which for the most part are based on conservative assumptions. The largest source of uncertainty is associated with the pattern and duration of the release of generic ketone. It is necessary to use an assumption since the only site-specific data available are a single estimate of total annual release; therefore the actual number of days where releases occur is unknown. The values shown in Table 1 were derived based on the assumption that releases of generic ketone take place continuously over 365 days per year. However, if releases actually occur over shorter periods, the model would estimate higher ambient air concentrations. The impact of different assumptions regarding the pattern of releases of generic ketone on the estimates of the ambient air concentration is shown in Table 2.

Table 2. Estimated Ambient Air Concentrations of Generic Ketone — Impact of Pattern of Release

If Releases Occurred...	Air Concentrations Would Increase By a Factor of...
Over 24 hours/day, but only on weekdays	1.5
Over 24 hours/day every day, but only 6 months/year	2

Over 365 days, but only one 8-hour shift per day	3
Over 24 hours/day every day, but only 1 month/year	12
Over 24 hours/day every day, but only 1 week/year	52

2.2 Modeling of Surface Water Concentration of Generic Ketone

The ReachScan model was used to estimate the surface water concentrations resulting from reported annual releases of generic ketone to surface water. ReachScan is a simple dilution model used to estimate steady-state chemical concentration in surface water bodies (mainly river reaches) due to a continuous loading from a single discharging facility. Several default parameters are used for the modeling including:

Duration of releases: Constant over 365 days per year
Distance of search: 200 km
Direction of search: Downstream
Type of search: Search for utilities
Flow type: Harmonic mean

The model provides stream concentration estimates at the reach where the releasing facility is located and at the reach where the drinking water utilities are located. In addition to the default assumptions listed above, it was also assumed that generic ketone was not removed in-stream (e.g., volatilization) or at the drinking water facility. Thus, the estimate of the stream concentration at the drinking water utility is assumed to be the same as the concentration in the drinking water.

As noted above, the greatest source of uncertainty pertains to the assumption that generic ketone is released continuously over 365 days per year. However, if releases actually occur over shorter periods, the model would estimate higher surface water concentrations. For example, if the releases occurred over 10 days per year, the value calculated for the surface water concentration would increase by a factor of 37. The value would increase by a factor of 12 or 1.5 if releases occurred over 30 days per year or 250 days per year, respectively.

2.3 Estimation of Acute Potential Dose Rates Via Drinking Water Consumption

The potential exposure of the population to releases of generic ketone to surface water would be through consumption of drinking water. Drinking water consumption can be calculated on a daily basis or it can be calculated as a lifetime average. The former estimate is generally referred to as the acute potential dose rate (APDR) and the later is generally referred to as the lifetime average daily dose (LADD). The APDR is calculated when the toxic effect of a chemical is thought to be the result of a short-term acute exposure, whereas the LADD is

calculated when the toxic effect is thought to be the result of long-term chronic exposure. For generic ketone, the primary concern is for potential developmental toxicity. A central assumption that is used in developmental toxicity risk assessments is that developmental effects can result from a single exposure to the chemical. Therefore, for this assessment, it is most appropriate to use estimates of the APDR.

In accordance with Agency guidelines for exposure assessment, the APDR was calculated using the following equation:

$$APDR = \frac{C \times IR \times CF1}{BW}$$

where:

C = surface water concentration (µg/l)
IR = water intake rate (l/day)
CF1 = conversion factor from µg to mg (0.001)
BW = body weight (kg)

The following assumptions were made:

C = Calculated using a simple dilution water model executed in ReachScan. The concentration in the water varies from facility to facility. Used the highest stream concentration estimated by ReachScan and assumed no removal
IR = 2 L/day, this value represents the high-end value for water consumption
CF = Conversion from µg to mg ($1.0e^{-3}$)
BW = 65 kg, this value represents adult females

The three facilities with the highest annual releases to surface water were modeled by ReachScan for this assessment. The estimated surface water concentrations and the associated drinking water APDRs are presented in Table 3. The concentration in the water ranged from 4.4 to 47 µg/L at the three highest drinking water utilities. The drinking water APDRs range from 1.4×10^{-4} to 1.4×10^{-3} mg/kg/day.

Table 3. Acute Exposures Resulting From Surface Water Releases

Facility	Estimated Surface Water Concentration (µg/L)[1]	Acute Potential Dose Rate (mg/kg/day)[1]
1	47	0.0014
2	9	0.00028

3	4.4	0.00014

[1] Assumes that the amount reported released to water in 1994 was released over 365 days/year.
If the number of release days were changed to 10, 30, or 250, the resulting surface water concentrations and APDR would increase by a factor of 37, 12 and 1.5, respectively.

2.4 Exposure Characterization

Ninety-nine percent of generic ketone released to the environment is through stack (point) and fugitive (area) emissions into the atmosphere. The remaining one percent of releases go to surface waters, landfill, and deep well injections. For this assessment, ambient air concentrations and surface water concentrations were estimated for the three facilities with the highest releases of generic ketone. These values were estimated through the use of two models, the ISCST3, and ReachScan models.

In the absence of site-specific information, each model requires the use of various default assumptions which introduce uncertainties into the analysis. The greatest uncertainty is due to the assumption regarding the number of days during the year that the facility releases generic ketone. This assumption arises because of the fact that facilities only report total annual releases and do not provide information on the pattern of the releases. For this assessment, it was assumed that the air and water releases of generic ketone occurred evenly over 365 days per year. However, the values calculated could be substantially higher if releases occurred for less than 24 hours per day (such as only during a 8 hour work shift) or occurred for less than 365 days per year.

APPENDIX D

MITEC CASE STUDY

Contents

EXECUTIVE SUMMARY . . . . . Page D-4

1. CONTEXT . . . . . Page D-6
   - 1.1 Background . . . . . Page D-6
   - 1.2 Planning and Scoping . . . . . Page D-7

2. RISK PARADIGM . . . . . Page D-9
   - 2.1 Hazard Identification and Dose Response . . . . . Page D-9
     - 2.1.1 Noncancer . . . . . Page D-9
       - Systemic Toxicity . . . . . Page D-9
       - Acute Toxicity . . . . . Page D-9
       - Route-to-Route Extrapolation . . . . . Page D-10
     - 2.1.2 Cancer . . . . . Page D-10
       - EPA's 1996 Cancer Risk Guidelines . . . . . Page D-10
       - EPA's Proposed Cancer Risk Guidelines . . . . . Page D-12
     - 2.1.3 FQPA Considerations . . . . . Page D-12
   - 2.2 Exposure Assessment . . . . . Page D-13
     - 2.2.1 Dietary Exposure (Food) . . . . . Page D-13
     - 2.2.2 Dietary Exposure (Drinking Water) . . . . . Page D-14
     - 2.2.3 Occupational and Residential Exposures . . . . . Page D-15
   - 2.3 Risk Calculations . . . . . Page D-15
     - 2.3.1 Occupational Noncancer Risks for Mixers/Loaders and Applicators . . . . . Page D-15
     - 2.3.2 Dietary (Food and Water) Risk . . . . . Page D-16
     - 2.3.3 Risk to Children . . . . . Page D-17
     - 2.3.4 Occupational and Residential Cancer Risks . . . . . Page D-18
   - 2.4 Strengths and Uncertainties . . . . . Page D-18
     - 2.4.1 Hazard Identification and Dose Response . . . . . Page D-18
     - 2.4.2 Dietary Exposure Estimates . . . . . Page D-19
     - 2.4.3 Occupational and Residential Exposure Estimates . . . . . Page D-20
     - 2.4.4 BigCorp's Risk Assessment . . . . . Page D-20

3. CONCLUSIONS . . . . . Page D-20

4. RECOMMENDATIONS REGARDING DATA GAPS . . . . . Page D-21

Tables

Table 1. Estimated cancer risk from selected commodities . . . . . Page D-16
Table 2. Comparison of Linear and Non-Linear Model Options . . . . . Page D-17

MITEC RISK CHARACTERIZATION

EXECUTIVE SUMMARY

Context

EPA's Office of Pesticide Programs (OPP) initiated the human health risk assessment of Mitec under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) reregistration process. Mitec is a miticide registered for agricultural use on field, fruit, nut, and vegetable crops. The preliminary risk assessment for Mitec showed potential "unreasonable adverse effects," according to FIFRA criteria. Therefore, OPP scientists and regulatory staff were faced with the task of determining what risk-mitigation measures might be needed. To accomplish this, the OPP Mitec team entered into risk mitigation discussions with the registrant, BigCorp. Just as these discussions were about to begin, another EPA office (outside the Pesticide Program) released DRAFT cancer risk assessment guidelines. These draft guidelines introduced some science policy changes which significantly impacted the Mitec risk assessment. These science policy changes are discussed in the case study.

Also during the reregistration process for Mitec, new pesticide legislation was introduced. On August 3, 1996, the Food Quality Protection Act of 1996 (FQPA) was signed into law. This Act amends the existing pesticide legislation, FIFRA and FFDCA is some important ways. FQPA requires EPA to make a safety finding of a "reasonable certainty of no harm"for every pesticide. FQPA further requires that EPA consider special sensitivity of infants and children to pesticides, as well as the aggregate exposure of the public to pesticide residues from all sources (such as food, water, and residential use), and the cumulative effect of pesticides with other pesticides which share a common mechanism of toxicity. For the Agency to proceed with the reregistration of Mitec, the risk assessment had to be revised to address the criteria mandated by FQPA.

Risk Paradigm

<u>Hazard Identification and Dose Response Assessment</u>

The OPP Hazard Identification Assessment Review Committee (HIARC) reviewed the entire toxicological database to identify appropriate toxicological endpoints to assess the dietary and occupational risks.

HIARC selected the endpoint of decreased maternal body weight gain from a rabbit developmental toxicity study to analyze risks from short- and intermediate-term exposures to agricultural workers. The No Observed Adverse Effect Level (NOAEL) for the rabbit developmental study was 6 mg/kg/day this value was used in the occupational risk assessment.

The HIARC also recommended further evaluation of the Mitec database for carcinogenicity potential by the OPP Cancer Assessment Review Committee (CARC) because the chronic rodent studies for Mitec showed carcinogenic activity. CARC reviewed the carcinogenicity of Mitec on two different occasions. At the first CARC, Mitec was classified as a Group B2 carcinogen according to EPA's 1986 Guidelines for Carcinogen Risk Assessment as a Group B2 carcinogen. The classification was based on two rat bioassays that showed undifferentiated jejunal sarcoma, a malignant and extremely rare tumor type. The second CARC was convened to evaluate Mitec's carcinogenicity in light of the proposed revisions to the Carcinogen Risk Assessment Guidelines. Based on the direction of the proposed revisions to the Guidelines, the CARC recommended evaluating cancer risk of Mitec using two methods.

The Food Quality Safety Act factor for the protection of infants and children was reduced to 1X based on the: (1) completeness of the toxicology database; (2) lack of evidence of increased susceptibility following pre- and post-natal exposures; and (3) the use of adequate data (actuals and surrogate) to satisfactorily assess dietary and non-dietary exposures.

Exposure Assessment

During the planning and scoping phase, OPP identified dietary and occupational exposure as the primary exposure pathways for Mitec. FQPA requires EPA to aggregate exposure from food, water, and residential exposure. Since Mitec is not likely to reach groundwater and surface water under most environmental conditions and there are no residual risks associated with Mitec use, only the dietary risk from food was included in the aggregate risk assessment. Occupational exposure is not assessed under FQPA, and is not included in the aggregate risk assessment.

OPP estimated potential dietary exposures from BigCorp's market basket survey, which provided actual residue monitoring data at the point of food distribution to grocery stores; monitoring data from the U.S. Department of Agriculture's (USDA's) Pesticide Data Program (PDP); field trials; and processing studies. OPP conducted the dietary risk analysis using the Dietary Exposure Evaluation Model (DEEM™), which estimates the percent of the acute and chronic population adjusted dose (PAD) contributed through the diet. OPP also used food consumption data from the 1989-1992 USDA CSFII survey to determine dietary food consumption patterns of commodities containing Mitec residues. OPP used information primarily from the Pesticide Handlers Exposure Database (PHED) to estimate potential exposures to mixers, loaders, and applicators as well as private growers and aerial applicators who use typical Mitec products.

Risk Characterization

Noncancer risks (Margin of Exposures, MOEs) were of low concern based upon limited exposure and minimal systemic toxicity. MOEs ranged from 33 to 30,000 for total exposure. Although mixer/loaders and applicators of Mitec on almonds and walnuts have systemic toxicity

MOEs less than 100, their exposure is likely to be of short duration. The severity of effect and route-to-route extrapolation further lessen OPP's concern. Uncertainty associated with the systemic toxicity endpoint has mainly to do with route-to-route extrapolation from oral gavage to dermal routes. Mixer/loaders and applicators are exposed to Mitec primarily by the dermal route and to a minor extent by inhalation. The method OPP used to estimate a dermal absorption factor of 6% has not been validated with pharmacokinetic studies.

Confidence in the basis for a dietary cancer risk and for exposure is high. The total dietary risk from all published agricultural uses of Mitec is 1.6×10^{-5} with exposure to children from apples, peaches, and grapes (2.5×10^{-7} to 9.1×10^{-6}) resulting in the major source of risk concern. Occupational cancer risks (skin exposure) ranged from 10^{-7} to 10^{-4} with high risks estimated for wettable powders on grapes (open and closed cabs) and commercial mixer/loaders (open mix system). Occupational cancer risks in the range of 10^{-4} to 10^{-6} are acceptable based upon the OPP Cancer Worker Risk Policy. OPP derived the Q_1* using the time-to-tumor statistical model, which HIARC and CARC believe is the most scientifically appropriate model for this case. Alternate (lower) cancer risks estimated by the registrant are not considered as scientifically valid since they do not account for time-to-tumor information.

The evidence for carcinogenicity and the evidence for systemic toxicity (decreased body weight gain) is strong. Rare and fatal tumors observed in two rat bioassays confirmed carcinogenicity. Three different species exhibited decreased body weight gain within a similar dose range.

OPP has high confidence in the dietary risk estimates. Two reliable sources of residue data (the market basket survey and USDA's PDP) are in close agreement, and OPP used the food consumption data from the 1989-1992 USDA CSFII survey, which is the latest survey available.

OPP has low overall confidence in many of the occupational exposure scenarios due to a low number of replicates or poor data quality. Therefore, the occupational exposure estimates should be considered preliminary.

1. CONTEXT

1.1 Background

EPA's Office of Pesticide Programs (OPP) initiated the human health risk assessment of Mitec under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) reregistration process. The 1988 Amendments to FIFRA requires EPA to reregister all pesticides first registered before November 1, 1984. Reregistration involves a thorough review of the scientific database underlying a pesticide's registration. The purpose of EPA's reregistration process under FIFRA was to reassess the potential hazards and risks arising from the currently registered uses of the pesticide according to modern standards; to determine whether the data requirements for

the pesticide have been satisfied and whether there is a need for additional data on health and environmental effects; and to determine whether the pesticide meets the "no unreasonable adverse effects" criteria of FIFRA. Because the risk assessment for Mitec showed potential "unreasonable adverse effects," OPP scientists and regulatory staff were faced with the task of determining what risk-mitigation measures may be needed. Therefore, the OPP Mitec team entered into risk mitigation discussions with the registrant, BigCorp. Just as the risk mitigation negotiations were about to begin, another EPA office (outside the Pesticide Program) released DRAFT Cancer Risk Assessment Guidelines for the Agency. These draft guidelines introduced some science policy changes that significantly impacted the Mitec risk assessment; these policy changes are discussed in the case study.

New pesticide legislation was introduced during the reregistration process for Mitec. On August 3, 1996, the Food Quality Protection Act of 1996 (FQPA) was signed into law, amending the existing pesticide legislation, FIFRA and FFDCA.. FQPA established a new regulatory standard, requiring EPA to make a safety finding of a "reasonable certainty of no harm"for every pesticide. To make this finding, FQPA requires EPA to consider certain criteria: (1) special sensitivity of infants and children to pesticides, (2) the aggregate exposure of the public to pesticide residues from all sources (such as food, water, and residential use), and (3) the cumulative effect of pesticides with other pesticides which share a common mechanism of toxicity. For OPP to proceed with the reregistration of Mitec, the risk assessment had to be revised to address the criteria mandated by FQPA.

Mitec is a miticide used on field, fruit, nut, and vegetable crops. Apples, grapes, oranges, peaches, almonds, walnuts, cotton, field corn, and mint comprise 80% of Mitec use in the United States. There are no residential (non-occupational) uses of Mitec. The most widely used Mitec products are the wettable powder and emulsifiable concentrate. BigCorp is the sole manufacturer and owner of Mitec, which is one of the last remaining miticides on the market. One of its major benefits is that it can be used in Integrated Pest Management (IPM) programs because it does not kill beneficial mites. There are few registered alternative miticides, but none of them spares beneficial mites.

1.2 Planning and Scoping

In planning the risk assessment, OPP considered how risk managers might use the risk assessment and focused on two options: (1) if the risks were unsafe, risk managers could adopt risk mitigation measures on any or all uses of Mitec to ensure conformance with the Agency's dietary and worker exposure standards for acceptable risk; and (2) if the risks were already within acceptable risk standards, risk managers could choose to take little or no action. OPP could then proceed with reregistration of Mitec.

During the planning and scoping phase, OPP identified dietary and occupational (mixer/loader, applicator, growers, commercial applicators) risks as the primary risks. Dietary

risk to children was of particular concern based on their food consumption patterns. OPP also used food consumption data from the 1989-1992 USDA Food Consumption Survey to determine dietary food consumption patterns of commodities containing Mitec residues. As the case study will demonstrate, commodities containing the highest residues of Mitec were also foods comprising a large part of a typical child's diet. preliminary estimates show that exposure to fresh fruit commodities comprise between 75 and 89% of the total dietary exposure of Mitec to adults, infants (non-nursing) less than one year of age, and children one to six years of age. For infants, exposure to processed fruit commodities contributes more than 82% of their total dietary exposure to fruits. However, despite the concern for children's exposure to Mitec on the basis of food consumption patterns, OPP does not have any evidence that children show any special sensitivity to Mitec.

OPP estimated potential exposures in the diet with data from BigCorp's market basket survey, monitoring data from the U.S. Department of Agriculture's (USDA's) Pesticide Data Program (PDP), field trials, and processing studies. OPP conducted the dietary risk analysis using the Dietary Exposure Evaluation Model (DEEM™), which estimates the percent of the acute and chronic population adjusted dose (PAD) consumed by each population group. (The PAD reflects the acute or chronic Reference Dose (RfD) for a chemical that has been adjusted to account for the FQPA safety factor, which, for Mitec, was 1X..) OPP also used the DEEM model to estimate cancer risk for the total US population. OPP used food consumption data from the 1989-1992 USDA Food Consumption survey to estimate dietary exposure to Mitec.

OPP used information primarily from the Pesticide Handlers Exposure Database (PHED) to estimate potential exposures to mixers, loaders, and applicators as well as private growers and aerial applicators using typical Mitec products.

The OPP Hazard Identification Assessment Review Committee (HIARC) reviewed the entire toxicological database and appropriate endpoints characterized for the dietary and occupational risks. The Committee's function was to validate the toxicity conclusions and choose appropriate endpoints for risk assessment. The HIARC recommended further evaluation of the database for Mitec carcinogenicity potential by the OPP Cancer Assessment Review Committee (CARC).

Acronyms

CARC	Cancer Assessment Review Committee
DEEM™	Dietary Exposure Evaluation Model
FQPA	Food Quality Protection Act
HIARC	Hazard Identification Assessment Review Committee
MOE	Margin of Exposure
OPP	EPA's Office of Pesticide Programs
PAD	Population Adjusted Dose (RfD adjusted for FQPA factor)
PDP	USDA's Pesticide Data Program
PHED	Pesticide Handlers Exposure Database
DWLOC	Drinking Water Level of Comparison

Although the Food Quality Protection Act was passed during the risk assessment process for Mitec, OPP determined that FQPA would not considerably change the risk assessment. The FQPA factor for the protection of infants and children was reduced to 1X for Mitec. In addition, no aggregate risk assessment was necessary because there is no residential exposure and water exposure is negligible. Further, Mitec is not believed to share a common mechanism of action with any other pesticides, so a cumulative risk assessment is not necessary.

2. RISK PARADIGM

This section summarizes the key information from the human health risk assessment on Mitec.

2.1 Hazard Identification and Dose Response

The HIARC reviewed the toxicological database for Mitec and determined that while cancer and systemic toxicity (i.e., decreased body weight gain) are the critical endpoints for risk assessment, workers may also experience acute, severe dermatitis due to Mitec's corrosive properties (see Section 2.1.1, Acute Toxicity).

2.1.1 Noncancer

Systemic Toxicity

HIARC evaluated the toxicological database for Mitec and selected an appropriate endpoint for assessing the noncancer risks associated with short (1-7 days) and intermediate (1 week-several months) term exposure to agricultural workers. Toxicity studies of relatively short duration were reviewed since most workers are only exposed to Mitec for a few days to a few weeks per year. The endpoint HIARC selected for short- and intermediate-term occupational exposures is decreased maternal body weight gain from a rabbit developmental toxicity study. The No Observed Adverse Effect Level (NOAEL) is 6 mg/kg/day. This NOAEL is supported by another rabbit developmental study and rat and dog chronic feeding studies with NOAELs in the range of 6-8 mg/kg/day.

Acute Toxicity

HIARC evaluated animal studies for effects related to acute toxicity, irritation, and dermal sensitization. The Committee also considered developmental toxicity data because developmental effects can result from a single exposure to a chemical. Mitec has low acute toxicity with most LD_{50} values >5 g/kg. Mitec is a reported skin and eye irritant in animals, and there are reports of severe dermatitis in farm workers reentering fields treated with Mitec in California. Further evaluation of this issue is underway (see Section 4.0, data gaps). HIARC

determined that the weight-of-evidence, including the developmental toxicity data, is insufficient to support an acute risk assessment.

Route-to-Route Extrapolation

The most appropriate toxicological studies for a human health risk assessment are by the oral route. However, because dermal contact is the primary exposure route for mixer/loader and applicator exposure (inhalation is expected to be a minor pathway and therefore a minor contributor to risk), OPP estimated an absorption factor for route-to-route extrapolation. There was no adequate dermal absorption study. OPP did this by comparing the NOAEL from a rabbit 21-day dermal toxicity study to the NOAEL for reduced maternal body weight gain from the oral rabbit developmental toxicity study. The systemic dermal absorption factor is estimated as follows:

$$\%\ \text{dermal absorption} \sim \frac{\text{systemic NOAEL rabbit oral developmental tox study}}{\text{systemic NOAEL rabbit 21-day dermal tox study}} \times 100$$

The rabbit 21-day dermal toxicity study on Mitec showed hematologic changes at the high dose of 100 mg/kg/day, but the investigators attributed this effect to secondary inflammation resulting from dermal irritation. Other signs of systemic toxicity, such as decreased body weight gain, were not observed at this dose. Therefore, 100 mg/kg/day was considered to be the NOAEL for the rabbit 21-day dermal toxicity study. The 6% dermal absorption factor was calculated as follows:

$$\%\ \text{dermal absorption} \sim \frac{6\ \text{mg/kg/day}}{100\ \text{mg/kg/day}} \times 100 = 6\%$$

HIARC concluded that the 6% dermal absorption factor is not likely to underestimate the risk.

2.1.2 Cancer

EPA's 1996 Cancer Risk Guidelines

Mitec is classified according to the EPA's 1986 Guidelines for Carcinogen Risk Assessment as a Group B2 carcinogen. OPP's risk assessors and OPP's CARC[2] based this classification on two rat bioassays that showed undifferentiated jejunal sarcoma, a malignant and extremely rare tumor type. In the first bioassay, OPP was concerned that the stabilizer, propylene oxide, a known carcinogen and mutagen could have influenced the results. However, tumors were confirmed with the second bioassay that used an epoxidized soybean oil stabilizer.

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1 This is a standard internal peer review conducted within OPP. The conclusions of the CARC have not been evaluated by an external peer review body, which normally is the OPP Scientific Advisory Panel.

Evidence for the induction of gene mutations in cultured mammalian cells and chromosome breaking ability in exposed mice contributed to the weight-of-evidence for carcinogenicity.

BigCorp proposed that Mitec is carcinogenic via a non-linear mechanism, where cell proliferation in the small intestine (jejunum) is followed by tumor formation. BigCorp submitted a short-term cell proliferation study to support their claim. HIARC and CARC reviewed these data and found that they are not sufficient to support the mechanistic claim. BigCorp is planning to conduct an additional 65-week cell proliferation study, and HIARC and CARC have provided BigCorp with comments on the protocol for this study.

No data, other than the cell proliferation data, submitted to OPP addressed a possible mode of action for Mitec tumor induction. HIARC and CARC determined that a low-dose extrapolation model for projected human exposures is the most appropriate model to use due to the lack of a plausible mode of action other than mutagenic activity, the rarity of the tumor type, the malignancy, and no evidence that the tumor induction is not relevant to humans.

The cancer mode of action has important risk assessment implications. If Mitec is carcinogenic by a non-linear mode of action and tumors are only found above a certain critical dose, then the Agency would use a non-linear model to evaluate human health risk, and risk numbers probably would be significantly lower (see Section 2.3.1).

CARC determined that the data from the first rat bioassay are adequate for dose-response quantification. The Mitec unit risk for cancer, called Q_1^*, is 1.71×10^{-1} $(mg/kg/day)^{-1}$ for males; the Q_1^* is in human equivalents. The Q_1^* is based on male rat fatal jejunum sarcoma and is estimated using the Time-to-Tumor Multistage Model and a body weight$^{3/4}$ interspecies scaling factor (the quantification did not include interim sacrificed animals). OPP used a time-to-tumor model fatal tumor analysis to account for dose related mortality and the high incidence of fatal sarcomas. The use of this extrapolation model assumes a linear dose-response relationship at lower doses. The Q_1^{*3} represents the slope of the 95% upper bound of the dose-response curve for jejunum sarcomas. Cancer risk estimates based on the Q_1^* are an estimate of the upper-bound risk as per Agency policy; the true value of the cancer risk is unknown.

BigCorp calculated a separate Q_1^* of 3.2×10^{-2} $(mg/kg/day)^{-1}$ using the Quantal Multistage Model, a slightly different statistical model than the one EPA used. The Quantal Multistage Model does not account for differential mortality and represents the geometric mean of the Q_1^* values for males and females from the same tumor data set. HIARC believes that this statistical model is inappropriate because it is necessary to account for differences in mortality noted between dose groups since death was from malignant, fatal tumors. The cancer risk estimates using the Time-to-Tumor Multistage Model versus the Quantal Multistage Model differ by a factor of ten.

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2 This upper-bound estimate of risk is generally thought to cover the range of human variability and EPA considers it to be inherently conservative of public health and may also overestimate the risk.

EPA's Proposed Cancer Risk Guidelines

Based on the direction of the proposed revisions to the Carcinogen Risk Assessment Guidelines, the CARC has evaluated risk using another linear extrapolation method. CARC has calculated an LED_{10} (lower bound of the 10% effective dose or ED_{10}) for Mitec using the time to tumor model. The LED_{10} is used as the point of departure from the observed data to draw a straight line to the origin for a low-dose extrapolation. The unit risk based on this line is very close to the Q_1^*. Thus, use of the LED_{10} does not significantly impact the cancer quantification or the projected risk estimates. The LED_{10} versus ED_{10} is the current Agency consensus for the point of departure stemming from the proposed Guidelines.

BigCorp submitted their own LED_{10} for Mitec (not presented). However, the company used the Quantal Multistage Model to fit the data, which CARC believes is inappropriate for the reason stated above.

2.1.3 FQPA Considerations

To comply with FQPA, OPP evaluated Mitec to determine whether infants and children showed any special sensitivity to Mitec, to determine the aggregate exposure of the public to Mitec residues from all sources (such as food, water, and residential use), and to determine the cumulative effect of Mitec and other pesticides which share a common mechanism of toxicity.

The FQPA Safety Factor Committee (1999) evaluated the Mitec to determine if an FQPA Safety Factor was warranted. The Committee concluded that Mitec does not indicate an increased susceptibility to infants and children. This is based on the pre-natal developmental toxicity studies in rats and rabbits that provided no indication of increased susceptibility of rat or rabbit fetuses to *in utero* exposure to Mitec.

OPP evaluated the potential exposure pathways for Mitec to determine aggregate exposure from all residue sources. The office concluded that Mitec had very little potential to contaminate drinking water. Mitec has no residential uses, so residential exposure is not anticipated. Therefore, aggregate exposure for Mitec only included dietary exposure from residues in food. OPP conducted an analysis to determine if Mitec was either structurally similar or showed similar toxicological effects to any other pesticide. The Office concluded that Mitec is did not share a common mechanism of action with any other currently registered pesticides, so a cumulative risk assessment is not necessary.

2.2 Exposure Assessment[4]

2.2.1 Dietary Exposure (Food)

FIFRA requires submission of residue chemistry data to support all food-use pesticides. A typical data set includes studies on (1) the nature of the pesticide residue in plants and animals; (2) the magnitude of the residue in treated crops, processed food and feed, and livestock commodities, such as meat, milk, and eggs; (3) reduction of residue during food processing; (4) analytical methods for detecting the residue(s); and (5) chemical identity. These data are used to determine the residue(s) of concern, establish tolerance levels for enforcement, and estimate "anticipated" residues of the pesticide in foods on a national level.

OPP calculated the anticipated residues for Mitec to provide a realistic picture of pesticide residues in foods and subsequent dietary exposure. The data used in this assessment were based on actual monitoring data at the point of distribution, i.e., market basket survey data and subsequent monitoring data from USDA's Pesticide Data Program (PDP). Market basket and/or PDP data were used for most commodities, particularly those that contributed a large portion of total dietary exposure.

Initially, BigCorp conducted a market basket survey for major food crops treated with Mitec. The market basket survey measured residues collected at the supermarket. Later, the USDA PDP collected residue data at regional food distribution centers explicitly for the dietary risk assessment. The USDA PDP data confirmed the results of the registrant's market basket survey. Anticipated residues are typically based on data from field trials, processing studies, FDA, USDA monitoring data, and market basket data, when available. Therefore, HIARC considered the residue data listed below for Mitec to be a realistic measure of actual residues on food. HIARC believes the exposure risks based on these data are not overestimated. Listed below are the commodities showing the highest number of detects from the market basket survey:

Commodities	% Detects	Detects/Total Samples
Apples	31%	62/200
Infant Apple Sauce	52%	103/200
Raisins	99%	197/200
Peaches	30%	44/146
Infant Peaches	40%	79/199

3 More detailed information regarding the basis for the dietary and occupational exposure assessments is available in the OPP Internal Review Document for Mitec (May 1997) and the supporting reviews. This includes information on the range of concentrations of Mitec noted in the detects in the commodity samples; use parameters for mixer/loaders and applicators of Mitec; and unit exposure estimates for dermal, hand, total dermal and inhalation exposures for these workers based on the PHED database.

OPP used food consumption data from the USDA's 1989-1992 survey to estimate dietary exposure. Data from the USDA are translated into food forms, which are the individual components of various foods. OPP calculated dietary exposure for Mitec by combining information on residues for various foods with food consumption patterns from the USDA survey to derive an average lifetime exposure estimate for Mitec.

OPP has extremely high confidence in the anticipated residue values used in the dietary risk assessment because they represent typical residues found in national supermarkets for the commodities tested, and OPP's and BigCorp's residue values are consistent.

2.2.2 Dietary Exposure (Drinking Water)

Drinking water exposure to pesticides can occur through groundwater and surface water contamination. EPA considers both acute (one day) and chronic (lifetime) drinking water risks and uses either modeling or actual monitoring data, if available, to estimate those risks. EPA determines the maximum allowable contribution of treated water allowed in the diet in a two step process that involves evaluating how much of the overall risk is contributed by food and determining a drinking water level of comparison (DWLOC). The Agency uses the DWLOC as a surrogate to capture risk associated with exposure from pesticides in drinking water. The DWLOC is the maximum concentration in drinking water which, when considered together with dietary and residential exposure, does not exceed a level of concern.

OPP based the estimates of Mitec concentrations in groundwater on the SCI-GROW model, which is a screening tool that provides a high-end estimate under "worst-case" conditions. OPP based the estimates of Mitec concentrations in surface water on the PRZM-EXAMS model, which is also a screening tool. Both of the models represent an upper-bound value in units of parts per billion.

EPA's Pesticides in Groundwater Database reports no detections in 3,341 samples that have been submitted to date for Mitec. This is consistent with the results of the laboratory and field dissipation studies, which showed no downward mobility of Mitec in soil.

Because Mitec is not likely to reach groundwater and surface water under most environmental conditions, and there are no residential risks associated with Mitec use, only the dietary risk from food is considered for the purpose of calculating the DWLOC . The DWLOC was then compared with the results of the SCI-GROW and PRZM-EXAMS models. The modeled concentrations of Mitec in surface and groundwater did not exceed the DWLOC . Therefore, drinking water risk below OPP's level of concern.

2.2.3 Occupational and Residential Exposures

Exposure estimates for mixer/loaders and applicators are estimated from the uses of Mitec on grapes, almonds, apples, peaches, oranges, walnuts, corn, and cotton because these crops represent high-volume uses of Mitec. The application methods evaluated in the analysis are the major agricultural methods used on the selected commodities, and they include airblast (for fruit and nut crops) and ground boom and aerial application for field crops (corn and cotton). OPP identified the tasks that could lead to occupational exposure to Mitec using the generic worker monitoring data available in the Pesticide Handlers Exposure Database (PHED) and usage data for Mitec in OPP's possession. PHED is used in lieu of adequate chemical-specific monitoring data. PHED may also be used in conjunction with adequate chemical-specific data to obtain a larger sample pool of monitoring replicates. Although BigCorp submitted worker exposure monitoring studies for Mitec, these studies were all of poor quality. They did not meet basic guideline requirements under subdivision U of the Pesticide Assessment Guidelines. No residential (non-occupational) uses or exposures are associated with Mitec.

2.3 Risk Calculations

2.3.1 Occupational Noncancer Risks for Mixers/Loaders and Applicators

For noncancer effects, OPP calculates margins of exposure (MOEs) as a measure of how close the estimated exposures come to a no-effect level in an animal study. For Mitec, OPP calculated MOEs for systemic toxicity (decreased weight gain) based on a NOAEL of 6 mg/kg/day for maternal toxicity from a rabbit developmental toxicity study. This effect was also noted in other oral studies in other species. OPP reported MOEs for mixer/loaders and applicators using maximum application rates designated on the label. OPP reported MOEs separately for inhalation and dermal exposure. Absorption through inhalation is assumed to be 100%, and 6% absorption is assumed for dermal exposure.

MOEs are calculated using the following equation:

$$\text{MOE} = \frac{\text{NOAEL (mg/kg/day)}}{\text{exposure (mg/kg/day)} \times \text{\% absorption}}$$

MOEs for Mitec ranged from 33 to 30,000 for total exposure. Uses with low MOEs (<100) for mixers/loaders or applicators included almonds and walnuts. Mixer/loaders using Mitec in a wettable powder formulation had MOEs (for total exposure) of 75 for almonds and 58 for walnuts. Growers (mixer/loader/applicators) had low MOEs (<100) for almonds and walnuts under the following exposure scenarios: wettable powder/open cab and wettable powder/closed cab. Label restrictions would preclude Mitec application by airblast in open cabs at the maximum rates for almonds and walnuts; this is the scenario that would otherwise be associated with MOEs of <50 for growers.

HIARC has low overall concern for the noncancer risk based on the best available exposure data, despite MOEs of less than 100. Mixer/loaders and applicators have systemic toxicity MOEs less than 100 with two crops: almonds and walnuts. For these crops, Mitec exposure is likely to be of short duration based on average farm size and average acreage treated per day. HIARC does not support the Mitec systemic toxicity endpoint for short duration or intermittent exposures. The severity of effect and route-to-route extrapolation further lessen HIARC's concern for potential systemic effects from Mitec exposure following treatment of almonds and walnuts.

2.3.2 Dietary (Food and Water) Risk

OPP estimated dietary cancer risks for Mitec using the low-dose extrapolation model. Cancer risk estimates are given for typical Mitec application rates. Dietary risk from all published uses is 1.6×10^{-5}. This total dietary cancer risk is the accumulation of all cancer risks calculated for each commodity using the following equation:

Extra cancer risk = Q_1^* x Anticipated Residue Contribution (ARC)

where $Q_1^* = 1.71 \times 10^{-1}$ (mg/kg/day)$^{-1}$ based on jejunum sarcoma in male rats
and ARC is calculated for each commodity based on anticipated residues and food consumption

A few commodities appeared to drive the risk; namely, apples, peaches, and grapes. Table 1 below presents the dietary risk from these individual commodities. Table 2 presents a comparison of total dietary risk from the linear and non-linear cancer risk models.

Table 1. Estimated cancer risk from selected commodities

Commodity	Cancer Risk Estimate	Comments
Apples, total	9.1×10^{-6}	Major contributor to total risk, high use, common children's food items
Fresh	6.1×10^{-6}	
Cooked/Canned	2.4×10^{-6}	
Juice	6.0×10^{-5}	
Peaches, total	2.5×10^{-6}	Major contributor to total risk
Grapes, total	1×10^{-6}	Major contributor to total risk common children's food item
Wine/sherry	4.4×10^{-7}	None

Raisins	2.5×10^{-7}	Common children's food item

The refined total dietary cancer risk for Mitec in the U.S. population was 1.6×10^{-5}. OPP has very high confidence in this estimate because it is based on actual residue data, the latest USDA food consumption data, a Q_1^* based on a rare tumor type, and a scientifically defensible dose-response extrapolation.

2.3.3 Risk to Children

Because high detects of Mitec residues are found in apples, raisins, and other commodities consumed by children in large quantities, OPP was particularly concerned about potential risks to children. the Agency does not have adequate methodology to address cancer risks to children at this time. A crude assessment was performed to give OPP risk managers information about potential cancer risks to children from short-term exposure to Mitec. As previously noted, OPP does not have any evidence that children show any special sensitivity to Mitec, so OPP assumed that Mitec would have the same cancer potency in children as it does in adults. OPP estimated cancer risk to children from a single year's exposure to Mitec in the event that Mitec residues remained in the food supply for up to a year. (Risk to children was estimated by this approach: annual risk was calculated according to exposure for each subgroup; this risk was then divided by 70 years to estimate annual risk). These risk estimates were calculated using food consumption values for nursing and non-nursing infants and children of various ages. Annual dietary risk for each subgroup was amortized over a 70-year lifetime, which assumed that children's food consumption patterns remained the same over a lifetime. A similar approach was used to calculate dietary cancer risk to children from alar.

Children's cancer risk from 1-year's exposure to Mitec was estimated to be in the 10^{-6} range.

Table 2. Comparison of Linear and Non-Linear Model Options

LINEAR RESPONSE AT LOW DOSE	MODEL	UNIT RISK ESTIMATE	TOTAL DIETARY RISK ESTIMATE	GROUP SUPPORTING USE OF MODEL
"one-hit" single dose could trigger sequence of events leading to cancer	Time-to-Tumor Multistage/Q_1^*	0.171	1.6×10^{-5}	USEPA
	Quantal Multistage/Q_1^*	0.032	2.9×10^{-6}	BigCorp

	Time-to-Tumor Multistage LED_{10}	0.160	1.5×10^{-5}	USEPA, 1996 Proposed Cancer Guidelines
NON-LINEAR tumors expected only above a critical dose	Margin of Exposure (MOE)	NOAEL = 4 mg/kg/day	MOE>40,000 (not of concern)	BigCorp

2.3.4 Occupational and Residential Cancer Risks

There are no residential (non-occupational) exposures and therefore no residential risks associated with the use of Mitec. However, risks via oral and dermal routes of exposure are associated with occupational uses of Mitec, and an absorption factor was estimated for route-to-route extrapolation for mixer/loader and applicator exposure scenarios (see Section 2.1.1).

Occupational cancer risks (skin exposure) ranged from one in ten million (10^{-7}) to one in ten thousand to (10^{-4}) with the highest risks estimated for growers that use wettable powders on grapes (open and closed cabs) and commercial mixer/loaders that support aerial sprayers (open mix system). These risks are within the range of acceptable risks (of 10^{-4} to 10^{-6}) set forth in OPP's Cancer Worker Risk Policy. OPP calculated the occupational cancer risk estimates using the Q_1^* value were calculated as follows:

Extra cancer risk = Q_1^* x LADD

where Q_1^* = 1.71×10^{-1} $(mg/kg/day)^{-1}$ based on jejunum sarcoma in male rats (oral bioassay)
and LADD = Lifetime average daily dose, worker exposure at typical application rate, amortized over a 70-year lifetime (with a 35-year work life) and adjusted for 6% dermal exposure.

2.4 Strengths and Uncertainties

The risk assessment for Mitec contains strengths and uncertainties based on the existing toxicological and exposure data, data gaps, and gaps in scientific knowledge. The assessment includes standard assumptions regarding: human body weight, work life, interspecies and intraspecies uncertainty (safety) factors, and other exposure parameters; interspecies extrapolation; and exposure prorated over a lifetime to estimate cancer risks. HIARC made additional assumptions regarding route-to-route extrapolation.

2.4.1 Hazard Identification and Dose Response

The existing evidence for the carcinogenicity endpoint is strong. The two rat bioassays and the rare and fatal tumor type—undifferentiated sarcoma of the jejunum—confirmed

carcinogenicity. CARC classified Mitec as a Group B2, probable human carcinogen. HIARC and CARC have high confidence in the statistical model used for the cancer dose-response assessment (Q_1^* and ED_{10}). The Q_1* is the 95th percent confidence limit of the dose-response curve, which is the default Agency policy. The actual cancer potency may be considerably less than estimated using this value. OPP derived the Q_1^* using the time-to-tumor statistical model because it incorporates the biological observations of dose-related mortality issues in the rodent bioassay. HIARC and CARC believe this model is the most scientifically appropriate model for this particular case. Although BigCorp proposed a potential non-linear mode of action, the database does not support this argument. CALEPA and HEALTH CANADA agree with EPA's interpretation of the data.

The evidence for the systemic toxicity endpoint (decreased weight gain) is also strong. Three species—rat, rabbit, and dog—exhibited this effect within a similar dose range. For the chronic rat and dog feeding studies and the rabbit developmental toxicity study (gavage), the NOAEL was within the range of 4-6 mg/kg/day with Lowest Observed Adverse Effect Levels (LOAELs) for all species based on decreased weight gain.

There is uncertainty regarding the relevance of the systemic toxicity endpoint to the anticipated exposure scenarios for Mitec. HIARC believes this endpoint is not relevant to single day, intermittent exposures. HIARC believes that repeated exposure would be required to produce this effect at levels to which humans are exposed. Growers who apply Mitec at the rate specified on the label would be exposed from 1 to 5 days per treatment and from 2 to 12 days per season. Exposure duration is likely to vary with farm size and the severity of the pest problem. Commercial applicators may be exposed throughout the treatment window for a particular crop and pest.

An additional area of uncertainty pertaining to the systemic toxicity endpoint is route-to-route extrapolation. Most of the toxicology data used to support the systemic endpoint are from studies with oral gavage or dietary administration. Investigators used oral gavage in the rabbit developmental study used for the risk assessment. However, mixer/loaders and applicators are exposed to Mitec by the dermal and inhalation routes. There are likely to be significant differences in absorption and pharmacokinetics between routes due to the bolus effect associated with oral gavage, local irritation seen with dermal dosing, and other factors. Another issue for consideration is severity of effect. Decreased weight gain is a relatively minor effect.

2.4.2 Dietary Exposure Estimates

OPP has extremely high confidence in these dietary risk estimates. Two highly reliable sources of residue data (the market basket survey and USDA's PDP) are in close agreement, and OPP used the food consumption data from the 1989-1992 USDA CSFII survey, which is the latest such survey available. OPP's analyses were based on a well designed market basket survey as recommended by the 1993 NAS report on *Pesticides in the Diets of Infants and Children*.

Overall, the Mitec case is one of the most refined dietary risk assessments ever performed in the Agency.

2.4.3 Occupational and Residential Exposure Estimates

OPP has low overall confidence in many of the occupational exposure scenarios due to a low number of replicates and/or poor data quality. There are no residential (non-occupational) uses of Mitec.

The occupational exposure estimates should be considered preliminary for a number of reasons. OPP limited the occupational exposure assessment to the major crops and application methods. For many of the scenarios evaluated, PHED exposure estimates were based on data sets with either low numbers of replicates and/or poor quality. Exposure scenarios with medium or high confidence include open mixing for liquid formulations, airblast application with closed cabs, and aerial spraying.

OPP based the exposure estimates for commercial applicators (for aerial spraying) on the maximum number of acres that could be treated in a given day. No information was available on the average acreage treated per year by commercial applicators. The best available information on pest control practices indicates that Mitec may be used up to 3 months per growing season. Therefore, to estimate cancer risk, the lifetime average daily dose for the cancer risk assessment was estimated for two scenarios: application of Mitec either 1-3 days/year or 5 days/week for 3 months for corn and cotton. The first scenario is likely an underestimate of lifetime exposure, and the second may be an overestimate.

2.4.4 BigCorp's Risk Assessment

In 1993, BigCorp submitted a dietary and occupational risk assessment that showed dietary risk to the total U.S. population of 1.53×10^{-6} to 9.25×10^{-10} and occupational risks in the range of mid 10^{-5} to 10^{-9}. However, BigCorp made significantly different assumptions from those the Agency used. BigCorp used a different Q_1^*, different residue values, and a different method of dietary analysis (Tolerance Assessment System or TAS). In addition, BigCorp rebutted many of the assumptions made in the current dietary risk assessment. However, OPP has discussed these differences in assumptions at great length internally and EPA scientists believe that the available data strongly support the Agency's position on the dietary cancer risks of Mitec.

3. CONCLUSIONS

The assessment of Mitec is the product of many choices in the assumptions used to address the uncertainties. In all risk analyses there are a range of mixes of choices that can be made. Of those that OPP considered reasonable for Mitec, occupational exposures give both the largest and least estimates of risk to workers. Our judgement for the best mix of choices made in

this assessment of the estimated risk is for dietary cancer among children, which was a value judgement based upon the risk estimates calculated, policy considerations for occupational risks including its voluntary nature, and differences in data quality between dietary and worker exposure data.

The total dietary risk from all published agricultural uses of Mitec is 1.6×10^{-5} with exposure to children from apples, peaches, and grapes (2.5×10^{-7} to 9.1×10^{-6}) resulting in the major source of risk concern. Occupational cancer risks (skin exposure) ranged from 10^{-7} to 10^{-4} with high risks estimated for wettable powders on grapes (open and closed cabs) and commercial mixer/loaders (open mix system). Occupational cancer risks in the range of 10^{-4} to 10^{-6} are acceptable based upon the OPP Cancer Worker Risk Policy.

Confidence in the basis for a dietary cancer risk and for exposure is high. Occupational exposure estimates are considered preliminary. Alternate (lower) cancer risks estimated by the registrant are not considered as scientifically valid since they do not account for time-to-tumor information. Noncancer risks (Margin of Exposures, MOEs) were of low concern based upon limited exposure and minimal systemic toxicity.

Although the Food Quality Protection Act was passed during the risk assessment process for Mitec, FQPA did not considerably change the risk assessment. As stated previously, the FQPA factor for the protection of infants and children was reduced to 1X for Mitec. In addition, no aggregate risk assessment was necessary because there is no residential exposure and water exposure is negligible. Further, Mitec is not believed to share a common mechanism of action with any other pesticides, so a cumulative risk assessment is not necessary.

4. RECOMMENDATIONS REGARDING DATA GAPS

4.1 BigCorp claims that Mitec is carcinogenic via a non-linear mechanism, where cell proliferation in the small intestinal (jejunum) is followed by tumor formation. To substantiate this claim, BigCorp is planning to conduct a 65-week cell proliferation study. If a threshold dose, indicating a non-linear mechanism for tumor formation, can be justified, the Agency is likely to consider using a different model that could significantly modify concerns about the risk.

4.2 Pharmacokinetic data are needed to verify the assumption of 6% dermal absorption as well as to validate the general use of ratios of oral and dermal NOAELs as a scientifically acceptable method of estimating dermal penetration.

4.3 High quality occupational exposure data are needed for the major crops Mitec is used on and application methods that agricultural workers use.

4.4 Additional investigation of exposures experienced by workers reentering fields treated with Mitec, including the adequacy of their protective equipment, is needed based on concems about Mitec's corrosive properties.

APPENDIX E

MIDLOTHIAN CASE STUDY

Multimedia Planning and Permitting Division
U.S. Environmental Protection Agency
Region 6
1445 Ross Avenue
Dallas, TX 75202

December 1998

Contents

EXECUTIVE SUMMARY . . . . . Page E-3

1. CONTEXT . . . . . Page E-6
   - 1.1 Scope and Purpose . . . . . Page E-6
   - 1.2 Characteristics of Study Area . . . . . Page E-7
   - 1.3 Context with Superfund . . . . . Page E-7

2. RISK PARADIGM . . . . . Page E-8
   - 2.1 Exposure Assessment . . . . . Page E-8
   - 2.2 Hazard Identification, Dose-Response, and Risk Estimation . . . . . Page E-10
   - 2.3 Limitations and Uncertainties . . . . . Page E-12
     - 2.3.1 Emission Rates . . . . . Page E-13
     - 2.3.2 Exposure Parameter Uncertainty . . . . . Page E-14
     - 2.3.3 Limitations of ISCSTDFT Air Modeling . . . . . Page E-15
     - 2.3.4 Uncertainty Associated with Exposure Scenarios . . . . . Page E-15

3. CONCLUSIONS . . . . . Page E-15

4. RECOMMENDATIONS REGARDING DATA GAPS . . . . . Page E-18

5. LITERATURE CITATIONS . . . . . Page E-19

Map 1 . . . . . Page E-25

Tables

Table 1. Overall Cancer Risk (Direct and Indirect) for All Carcinogenic Chemicals . . Page E-10
Table 2. Comparison of Modeled and Measured Concentrations . . . . . Page E-16
Table 3. Comparison of Unit Deposition Rates and Air Concentrations at Point 3 . . . Page E-17
Table 4. Comparison of Emission Rates . . . . . Page E-17

Midlothian Cumulative Risk Assessment Risk Characterization

EXECUTIVE SUMMARY

Context

EPA Region 6 prepared a risk assessment in support of the RCRA permitting process and in response to citizens' concerns about the permitted burning of hazardous waste in a cement kiln by Texas Industries (TXI) of Midlothian, Texas, which is approximately 30 miles south of the Dallas-Ft. Worth metropolitan area. Because of the close proximity of a steel company and two other cement manufacturing companies, Region 6 included emissions from all four industrial facilities in the risk assessment. Chaparral Steel Corporation is 0.7 miles southwest of TXI, and North Texas Cement Company and Holnam Cement Company are approximately 4 and 5 miles northeast of TXI, respectively. From TXI, the study area extends 3 miles south, 3 miles east, 6 miles west, and 8 miles north to Joe Pool Lake, which supplies drinking water to the study area.

With the exception of the City of Midlothian (approximate population of 5,100), located approximately 3 miles northeast of TXI, the land use of the study area is predominately agricultural with some industrial development. The area is home to several small cattle operations and rural residential developments. Many homes in the area have gardens. In addition to Joe Pool Lake, the area contains two privately owned lakes known as Soil Conservation Service (SCS) Lakes 9 and 10.

Risk Paradigm

Exposure

The risk assessment presents an overview of screening level risk estimates for direct (i.e., drinking water consumption and inhalation) and indirect (i.e., food consumption) exposures attributable to emissions from the three cement companies and the steel mill. Risk assessors considered four types of exposed individuals: the subsistence farmer, adult resident, child resident, and subsistence fisher as suggested in the draft *Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes* (U.S. EPA, 1994). Since overall risks for each pathway could vary according to which contaminant was deposited at the highest rate at a particular location or was present at the highest ambient air location, the risk assessors considered multiple receptor locations for each exposure scenario to ensure that the maximum media concentrations of each pollutant were considered.

EPA evaluated the most current information available to estimate the probability of potential impacts to human health, both directly via inhalation, incidental soil ingestion, and drinking water (via surface water intakes), and indirectly via modeled deposition and uptake through the food chain. Because the drinking water supplied to the area surrounding the facilities

comes from one source—Joe Pool Lake—exposure via contaminated drinking water from this source was considered under all of the scenarios.

The predominant sources of risk from the four industries were evaluated by comparing the emission rates and the unit-combined deposition and air concentrations associated with each facility. The indirect exposure air model used in this analysis is the only EPA-recommended air dispersion and deposition model for addressing a variety of exposure pathways important for chemicals that bioaccumulate and persist in the environment.

Effect and Risk Estimation

No cancer risk above regulatory levels of concern was identified. The most significant theoretical cancer risk would result from the ingestion of fish caught from SCS Lakes 9 & 10, and arsenic contributes up to 80% of this risk.

Risk assessment results based on theoretical and conservative modeling indicate a potential for non-cancer health effects from exposure to antimony in drinking water, and to cadmium and mercury through the ingestion of fish from SCS Lakes 9 & 10. However, actual site data (for soil and water samples near residents and fishing areas) indicate that the models over-predict media concentrations of the principle contaminants, antimony and cadmium, which drive the potential for theoretical non-cancer health effects.

Region 6 found no basis for federal regulatory action in regards to potential mercury risks. Borderline potential effects predicted in the risk assessment represent conservative estimates of risk for this compound. Also, measured media concentrations of mercury are within the range of U.S. background concentrations of mercury. In addition, the Texas Natural Resources and Conservation Commission found in 1995 that concentrations of mercury in the Midlothian area are equal to or lower than local and U.S. background levels.

The lack of good quality chemical-specific emission rates presents one of the largest sources of uncertainty associated with this screening level risk assessment. Another significant source of uncertainty overall is that the compound-specific allocation of emissions for the steel mill is based on the assumption that baghouse and fugitive emissions contained concentrations of contaminants similar to those found in steel mill baghouse dust. Another area of uncertainty concerns the use of standard EPA default values in the analysis. These include inhalation and consumption rates, body weight, and exposure duration and frequency, which are used in most EPA risk assessments. Using a single-point estimate for these variables rather than exposure parameter probability distributions ignores a variability that may influence the results by up to a factor of two or three.

Taking the uncertainties into account, the conclusions of the screening level risk assessment are that there are no cancer risks. Nor is there a potential for non-cancer health

effects above regulatory levels of concern even though conservative, theoretical models estimate exposures equal to or slightly above threshold levels for potential non-cancer effects. The majority of the potential for theoretical non-cancer health effects associated with antimony and cadmium results from the steel mill, not the cement manufacturing facilities. Theoretical exposures of concern for antimony, cadmium, and mercury are in the "borderline" range (equal to or barely over the threshold). Furthermore, Region 6 believes that using alternative approaches or information would likely lower the estimated risks and therefore strengthen the conclusion. Finally, actual measured concentrations of those contaminants that result in exposures above threshold values appear to be present in media at concentrations less than modeled concentrations.

1. CONTEXT

1.1 Scope and Purpose

EPA Region 6 initiated a risk assessment in response to concerns expressed by the citizens of Midlothian, Texas, over the proposed burning of hazardous waste at a cement kiln owned by Texas Industries (TXI). TXI had applied to the Texas Natural Resources and Conservation Commission for a RCRA permit to burn the hazardous wastes. Citizens primarily were concerned with the cumulative health effects from air emissions from TXI, and the emissions from two other cement kilns and a steel mill in the vicinity. In the course of the risk assessment, citizens also requested that Region 6 consider risk to infants from dioxin, via the breast milk pathway, and from a tire fire that occurred at a tire shredding facility in December 1995.

This risk characterization presents an overview of screening level risk estimates for direct (i.e., drinking water consumption and inhalation) and indirect (i.e., food consumption) exposures attributable to emissions from the three cement companies and steel mill. The risk screening document, *Midlothian Cumulative Risk Assessment*, was written by risk assessors in Region 6's Multimedia Planning and Permitting Division. Region 6 developed the estimates following the procedures outlined in the EPA's draft *Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes* (1994).

Risk assessors modeled emissions associated with the combustion sources using facility-specific emission rates, stack characteristics, and representative receptor locations around the facility. The types of receptors (exposed individuals) that were considered include an adult and child resident, a subsistence farmer, and a subsistence fisher (see further discussion under Section 2.1).

The risk estimates presented in this risk characterization are limited by the uncertainties inherent in the models used to estimate risk and in the data used in the models. Region 6 attempted to minimize uncertainties by:

a) evaluating and incorporating site-specific data collected by the Texas Natural Resource Conservation Commission,
b) requesting actual air emission rates from each of the facilities,
c) estimating emission rates based on tests conducted at similar facilities when specific rates were not provided, and
d) comparing the data provided for the facilities to data from other sources to evaluate its overall reasonableness.

The final risk assessment report was submitted to the Texas Natural Resources and Conservation Commission (TNRCC) to support their development of TXI's hazardous waste

burning permit. Results of the report also were provided to concerned citizens groups, mayors and industry representatives.

1.2 Characteristics of Study Area

Midlothian is located approximately 30 miles south of the Dallas-Ft. Worth metropolitan area. The study area extends 8 miles north, 3 miles south, 3 miles east, and 6 miles west of TXI (Map 1). Chaparral Steel Corporation (CSC) is 0.7 miles southwest of TXI, and North Texas Cement Company (NTCC) and Holnam Cement Company are approximately 4 and 5 miles northeast of TXI, respectively.

The study area is characterized by small hills and valleys with elevations ranging from approximately 800 feet above mean sea level south of TXI to 500 feet above mean sea level at Joe Pool Lake to the north. The predominant wind direction is from the south.

With the exception of the City of Midlothian (approximate population of 5,100), which is located approximately 3 miles northeast of TXI, the land use of the study area is predominately agricultural with some industrial development. The area is home to several small cattle operations and rural residential developments. Gardens were observed at many homes in the area during several site visits.

In addition to Joe Pool Lake (surface area approximately 7,600 acres), the area contains two privately owned lakes known as Soil Conservation Service (SCS) Lakes 9 and 10 (combined surface area of approximately 84 acres). SCS Lakes 9 & 10 are approximately 2 to 3 miles northwest and north, respectively, of the CSC/TXI complex, and very near residential developments.

1.3 Context with Superfund

In the Superfund program, EPA established a theoretical value of an excess acceptable lifetime cancer risk that ranges from one in ten thousand to one in one million. This range may be expressed as 1×10^{-4} to 1×10^{-6}. For example, a risk of 1×10^{-6} means that 1 person out of one million could develop cancer as a result of a lifetime exposure to emissions from the four facilities studied in this risk assessment. In the Superfund program, EPA must consider the need to conduct remedial action (cleanup) at a site if the theoretical risk exceeds 1×10^{-6}; EPA usually requires remedial action at locations where the calculated number of excess cancer risks is greater than 1×10^{-4} (one excess cancer case in a population of ten thousand people could potentially occur).

The level of concern for non-carcinogenic contaminants is determined by calculating a Hazard Quotient (HQ) or Hazard Index (HI). An HI is the sum of the HQs for several chemicals that affect the same target organ. If the HQ or HI equals or exceeds one, there may be concern

for potential exposure to site contaminants. EPA typically considers the need for remedial action at locations where the HQ or HI values equal or are slightly greater than 1.0 for people who may reasonably be expected to be exposed. EPA usually requires remedial action at locations where HQ or HI values significantly exceed one.

2. RISK PARADIGM

2.1 Exposure Assessment

The four types of exposed individuals considered in this screening level risk assessment are the subsistence farmer, the adult and child resident, and the subsistence fisher as suggested in the draft *Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes* (U.S. EPA, 1994). The individuals considered in each of the exposure scenarios were assumed to be exposed to contaminants from the emission sources via inhalation of particles and vapors, ingestion of above-ground vegetables, incidental ingestion of soil, and consumption of drinking water. The exposed individuals differed primarily in their consumption of certain foods. Specifically, only the subsistence farmer was assumed to consume contaminated beef and milk, while only the subsistence fisher was assumed to consume contaminated fish. Because the drinking water supplied to the area surrounding the facilities comes from Joe Pool Lake, exposure via contaminated drinking water was considered under all of the scenarios.

Although the difference in the amount of food consumed is the primary difference between the types of exposed individuals, other differences exist. The ingestion rate of soil and above-ground vegetables and the inhalation rate of air differ for children and the adults. Exposure duration is another difference. The adult resident and fisher are assumed to be exposed to the contaminants for 30 years, the subsistence farmer for 40 years, and the child exposed for 6 years.

The three water bodies considered in the risk analysis were selected based on information collected during a visit to Midlothian. These water bodies—Joe Pool Lake, SCS Lake 9, and SCS Lake 10—and their watersheds were those that were large enough to support fish and would experience the highest impact from the facilities' emissions, due to their location. U.S. Geologic Survey (USGS) topographic maps were used to delineate the watersheds associated with the three water bodies and to estimate water body and watershed surface areas.

According to the Texas Department of Health, Joe Pool Lake is the City of Midlothian's primary drinking water source, so it was used as such in the modeling efforts. The watershed of SCS Lakes 9 & 10 is a subsection of the Joe Pool Lake watershed that includes Cottonwood Creek and portions of the Newton Branch of Soap Creek. The assumption that the SCS Lakes watersheds are sufficient to support subsistence fishing is conservative because it has not been determined that they are able to support subsistence fishing. Furthermore, both lakes are

privately owned and SCS Lake 10 is on property with posted "No Trespassing" signs. Nevertheless, Region 6 assumed that these water bodies could support subsistence activity based on their size and their proximity to residential development.

Contaminants were assumed to be emitted from the four facilities 24 hours per day, 7 days per week, and 365 days per year. EPA's draft air dispersion model ISCSTDFT (Industrial Source Complex Sort-Term) was employed to estimate the transport of airborne contaminants to the surrounding area. Soil was assumed to become contaminated by wet and dry deposition of particles and vapors from the air. Above-ground vegetation for human and animal consumption was assumed to become contaminated via deposition of particles on plants, transfer of vapor phase contaminants to the vegetation, and uptake of soil and water contaminants through the roots. Beef and milk were assumed to be contaminated via ingestion by cattle of contaminated forage, silage, grain, and soil. Fish and the drinking water sources were assumed to be contaminated by surface runoff and the deposition of particles directly onto the water body.

Map 1 shows the points of maximum air concentration (D, E, and F) and combined deposition (A, B, and C) generated by the model based on estimated constituent-specific emission rates. For each compound group, these points were typically located close to the facility emitting the compound at the highest rate. Map 1 also shows the general locations (A_1, B_1, C_1) of the site-specific receptors to be evaluated in the study as suggested by the model. Based on land use maps for the area, subsistence farming was not a reasonable use for location C_1, so risk to subsistence farmers was calculated at an agricultural area to the north represented by point C_3.

Rather than estimate theoretical worst-case risk, Region 6 identified (through site visits) several potential residences and farms likely to be most impacted by the facilities[5]. Three site-specific residents, subsistence fishers, and subsistence farmers were identified for use in the modeling analysis (Table 1). Three of each type of exposed individual were considered to ensure that the maximum concentrations of each pollutant were taken into account, because the overall risks for each pathway can vary according to which contaminant is deposited the fastest or is present at the highest ambient air location. Resident A1 and subsistence farmer A1, resident B1, and resident C1 and subsistence farmer C3 are the exposed individuals located closest to the points of maximum combined deposition A, B, and C, respectively. The exposed individuals assumed to live at residence A1, B1, and C1 included the adult and child resident and the subsistence fisher. The difference between the adult resident and subsistence fisher was that the fisher was additionally exposed through the consumption of contaminated fish.

[5] It should be noted that these locations do not necessarily reflect actual residences and farms based on interviews etc., but rather reflect a reasonably conservative analysis of activities as seen from driving in and about the study area. For example, residential locations typically correspond to locations of houses or similar residential-type structures. Farms were estimated based on the presence of livestock or barn type structures in the area of interest.

2.2 Hazard Identification, Dose-Response, and Risk Estimation

No cancer risk above regulatory levels of concern was identified. As shown in Map 1, the most significant theoretical cancer risk, 1×10^{-4}, would occur for a subsistence fisher at point B1 who eats fish from SCS Lakes 9 and10. Arsenic contributes up to 80% of this risk. Other exposure scenarios that result in theoretical risk near regulatory levels of concern are subsistence farming and subsistence fishing in Joe Pool Lake. A combination of organic contaminants, including dioxin, BAP, and DEHP, drive the subsistence farming risk, while arsenic dominates the subsistence fishing risk at Joe Pool Lake.

The conservative, theoretical modeling results indicate the potential for non-cancer health effects. The modeled estimates of antimony and cadmium concentrations drive the potential for non-cancer health effects. Actual soil and water samples collected near residents and fishing areas, however, indicate that the models over-predict media concentrations of antimony and cadmium.

Risk assessment results based on theoretical modeling show a potential for non-cancer effects because some of the calculated HQs are greater than or equal to one. The HQ for exposure to antimony in drinking water is estimated to be three for adults and six for children at every receptor location. The HQ for the ingestion of cadmium in fish from SCS Lakes 9 and 10 equals one for the subsistence fisher; and the HQ for the ingestion of mercury in fish from both the SCS lakes and Joe Pool Lake equals one for the subsistence fisher.

The chronic oral reference dose for antimony (0.0004 mg/kg/day) contains an uncertainty of factor of 1,000. An uncertainty factor of 1,000 means that the critical amount of antimony found in laboratory studies to cause potential non-cancer health effects was multiplied by 1,000 to account for uncertainties in the studies before the amount was used in this study to estimate the potential for non-cancer health effects. Critical health effects from animal studies upon which the reference dose is based include a decrease in median life span, a decrease in non-fasting blood glucose levels, altered cholesterol levels, and a decrease in the mean heart weight of males. Table 1 presents the overall results of the risk assessment process.

Table 1. Overall Cancer Risk (Direct and Indirect) for All Carcinogenic Chemicals Associated with the Four Facilities

Scenario	Theoretical Risks
	Point A1
Adult Resident	7×10^{-6}
Child Resident	3×10^{-6}

Scenario	Theoretical Risks	
Subsistence Fisher	SCS Lakes 9 and 10 9×10^{-5}	Joe Pool Lake 3×10^{-5}
Subsistence Farmer	5×10^{-5}	
	Point B1	
Adult Resident	3×10^{-5}	
Child Resident	1×10^{-5}	
Subsistence Fisher	SCS Lakes 9 and 10 1×10^{-4}	Joe Pool Lake 5×10^{-5}
Subsistence Farmer	4×10^{-5}	
	Point C1	
Adult Resident	4×10^{-5}	
Child Resident	2×10^{-5}	
Subsistence Fisher	SCS Lakes 9 and 10 1×10^{-4}	Joe Pool Lake 6×10^{-5}
Subsistence Farmer	6×10^{-5} (Point C3)	

The chronic reference doses for cadmium (0.001 mg/kg/day for food and 0.0005 mg/kg/day for water) contain an uncertainty factor of 10. Critical human health effects attributed to cadmium include anemia and pulmonary disease, edema, pneumonitis, possible effects on the endocrine system, defects in sensory function, and bone damage.

Region 6 also considered risk to infants from dioxin via the breast milk pathway from a tire fire that occurred at a Midlothian tire shredding facility in December 1995. To address the risk via the breastmilk pathway, Region 6 used the draft screening guidance methodology to estimate an infant's daily intake of dioxin if the mother were a resident, subsistence farmer, or subsistence fisher. These estimated intakes were then compared to an infant's background exposure to dioxin through ingestion of breast milk. Based on the modeled values, an infant's estimated daily intake of dioxin is 0.01 pg/kg/day if the mother is a resident, 0.45 pg/kg/day if the mother is a subsistence farmer, and 0.38 pg/kg/day if the mother is a subsistence fisher. All of these intakes are less than 1% of the average daily dose (50 pg/kg/day) an infant would obtain from background levels of dioxin in breast milk.

Region 6 considered including the risk effects of the December tire fire in this assessment, but was unable to complete the evaluation because of a lack of actual emission rates of contaminants during the tire fire. Furthermore, there is uncertainty associated with using a methodology based on long-term chronic exposures to estimate the effects from a short-term event like a tire fire.

Finally, Region 6 conducted a qualitative analysis of the combined effects of windblown cement kiln dust (CKD) and contaminant emissions. This analysis was conducted by comparing "best estimates" of high-end baseline risks, listed in EPA's *Report to Congress on Cement Kiln Dust* (U.S. EPA, 1993), to the maximum theoretical risk estimates discussed above. For example, the most significant cancer risk identified in this risk characterization is 1×10^{-4} to a subsistence fisher. Pathways contributing to this level of risk include ingestion of fish, ingestion of drinking water, incidental ingestion of soil, ingestion of vegetables, and inhalation. According to the *Report to Congress on Cement Kiln Dust*, the "best estimate" of high-end baseline risk from the ingestion of fish contaminated with CKD is 4×10^{-6}. Risk from ingestion of surface water contaminated by CKD emissions are estimated at 1×10^{-8}, and risk from the ingestion of soil contaminated by CKD is estimated at 1×10^{-7}. Risk from ingestion of vegetables is estimated at 2×10^{-6}, and risk from inhalation is estimated at 2×10^{-12}. All of these risks added together do not substantially affect the most risk estimate of 1×10^{-4}. Thus, the uncertainty associated with the failure to quantitatively assess risk from the emissions of cement kiln dust does not appear to be significant.

A quantitative analysis of the combined effects of windblown CKD and contaminant emissions could not be performed because the exposure assumptions and fate and transport methodologies used in the two studies contain some differences. However, the comparison does provide a general feel for the overall contribution of CKD emissions to the theoretical risk estimated for the area.

2.3 Limitations and Uncertainties

This section discusses the limitations and uncertainties associated with this screening level cumulative risk assessment. The degree to which the uncertainty needs to be quantified and the amount of uncertainty that is acceptable varies with the intent of the analysis. For a screening level analysis such as this, a high degree of uncertainty is often acceptable, provided that conservative assumptions are used to bias potential error toward protecting human health.

Uncertainty can be introduced into a health risk assessment at every step in the process. Risk assessment is a complex process, requiring the integration of:

a) The release of pollutants into the environment
b) The fate and transport of pollutants in a variety of environments by processes that are often poorly understood or too complex to quantify accurately

c) The potential for adverse health effects in humans as extrapolated from animal bioassays
d) The probability of adverse effects in a human population that is highly variable genetically, in age, in activity level, and in life style

While a more sophisticated risk assessment may substantially reduce the uncertainty in both the assumptions and models utilized in this screening assessment, it is not possible to eliminate all uncertainty.

Uncertainty of data used to estimate risk or potential health effects for emission rate data, exposure parameters, air modeling, and exposure scenarios are described in the following sections. The term "significant" uncertainty is defined here as an uncertainty that results in a potential error in risk estimates which could raise or lower values above or below regulatory levels of concern.

2.3.1 Emission Rates

The lack of good quality chemical-specific emission rates presented one of the largest sources of uncertainty associated with this screening level assessment. For the cement manufacturing companies, the majority of the emission rates were based on trial burn data from NTCC. Because there were only limited data and limited information on the quality of the data obtained during the trial burns (e.g., percent recovered) and on the representativeness of the operating conditions during the trial burns, the representativeness of the emission rates could not be fully evaluated. To address this source of uncertainty, the emission rates used in the analysis were compared to available data sources (i.e., trial burn data, TNRCC data, and company-reported data) to ensure that the selected emission rates were reasonable yet conservative enough to allow for operational upsets and the uncertainty associated with the quality of the data. Region 6 is confident that the rates presented are as reasonable as can be provided given the availability of accurate data. In fact, one of the outside reviewers noted that emission rates for dioxin were consistent with EPA's experience in preparing the draft report *Estimating Exposure to Dioxin-Like Compounds* (1994a).

Another significant source of uncertainty in the overall process is the compound-specific allocation of emissions for CSC based on the assumption that baghouse and fugitive emissions contained concentrations of contaminants similar to those found in steel mill baghouse dust. It is unlikely that fugitive baghouse emissions to the atmosphere would contain contaminant concentrations greater than those found in the baghouse dust. However, it is possible that the fugitive emissions contain higher concentrations than those found in the baghouse dust since they are emissions that have not yet been treated. The volume of fugitive emissions could be more or less than assumed in this study because CSC's actual fugitive emissions have not been measured. As a result, the uncertainty in the emission estimates for CSC are significant.

One area of uncertainty that has been addressed since the review of the draft report by outside experts is the uncertainty associated with assumed baghouse dust emissions profile. The emissions allocation profile used to estimate emissions sets forth concentrations of contaminants that are very similar to CSC's baghouse dust data, with the exception of antimony and hexavalent chromium concentrations, which were not included in the profile. The actual amounts of antimony and hexavalent chromium emitted by CSC are unknown. The lack of any method to assess that accuracy of the antimony and hexavalent chromium emissions estimates is significant because both of these contaminants contribute to the overall cancer risks and non-cancer effects estimates. Antimony emissions were based solely on the baghouse dust profile contained in the *Detailed Summary of Information Collection Request Responses For Electric Arc Furnaces* (ICR). The ICR is based upon data from both stainless and non-stainless steel mill facilities; however, CSC reportedly operates a non-stainless steel mill. Hexavalent chromium emissions were estimated by assuming that the hexavalent chromium emissions constituted only two percent of total chromium emissions. This assumption is based on a table included in the Agency for Toxic Substances and Disease Registry's *Toxicological Profile for Chromium*.

2.3.2 Exposure Parameter Uncertainty

Another source of uncertainty involves the use of standard EPA default values in the analysis. These include inhalation and consumption rates, body weight, and exposure duration and frequency, which are used in most EPA risk assessments. These values often assume that the exposed population is homogenous, when in fact variations exist among the population. Using a single point estimate for these variables rather than exposure parameter probability distributions ignores a variability that may influence the results by up to a factor of two or three.

Other data subject to uncertainty are estimates of the chemical concentration in the media and locations of interest. For example, because no site-specific data of sufficient quality were available, the Worth National Weather Station provided an approximation of the meteorological conditions at the site. Different meteorologic conditions can influence the risk results by up to an order of magnitude given the same facility characteristics and surrounding land uses.

Another area of uncertainty is the use of EPA-verified cancer slope factors, reference doses, and reference concentrations. Single point estimates of these health benchmarks are used throughout the analysis. These benchmarks have both uncertainty and variability associated with them. However, the EPA has developed a process for setting verified health benchmark values to be used in all EPA risk assessments. These benchmarks are derived to be conservative and project upper bound risk estimates. With the exception of the dioxin and BaP toxicity equivalency methodology, all health benchmarks used in this analysis are verified through the EPA's work groups and are available on the EPA's Integrated Risk Information System (IRIS).

2.3.3 Limitations of ISCSTDFT Air Modeling

ISCSTDFT, the indirect exposure air model used in this analysis, is EPA's current method of addressing a variety of exposure pathways important for chemicals that bioaccumulate and persist in the environment. ISCSTDFT was released as a draft and has not been widely applied in the present form. Implementation of ISCSTDFT requires air dispersion modeling results for wet and dry depositions and air concentrations of particles and vapors in a variety of settings. ISCSTDFT is the only EPA-recommended air dispersion and deposition model currently available to provide such estimates from combustion sources located in both complex and non-complex terrains (U.S. EPA, 1994d).

2.3.4 Uncertainty Associated with Exposure Scenarios

The exposure scenarios included in this screening level assessment include an adult and child resident, a subsistence fisher and a subsistence farmer. Although a distribution of the characteristics (e.g., consumption rates) of each type of receptor are reasonably well characterized, population distributions for the modeled behaviors and activities have not been adequately studied. For example, little is known about the fraction of the general population that consists of subsistence farmers and fishers. Without population distributions for these receptors, the number of people likely to be exposed to contaminated media cannot be determined; therefore, the appropriateness of the receptors cannot be evaluated from the standpoint of population risk.

3. CONCLUSIONS

The conclusions of this conservative screening level risk assessment are:

1. Available site data show that there are no cancer risks; nor is there a potential for non-cancer health effects above regulatory levels of concern even though conservative, theoretical models estimate exposures equal to or slightly above threshold levels for potential non-cancer effects.

2. CSC is the primary source of the theoretical exposures above threshold levels, not the cement companies.

Region 6 arrived at the first conclusion for two reasons. First, they believe that the models and exposure scenarios upon which the estimates of risks and potential non-cancer health effects are thought to occur are conservative. The experts who reviewed the risk characterization report concurred that the risk assessment is conservative. Because the risk assessment is conservative, actual risks and exposures are likely to be less than the estimated risk and exposures. Given this conservatism and the fact that the theoretical exposures of concern for antimony, cadmium, and mercury are in the "borderline" range (equal to or barely over the

threshold), Region 6 cannot currently justify the need for immediate regulatory action. Furthermore, Region 6 believes that using alternative approaches or information would likely lower the estimated risks and therefore strengthen the conclusion.

Second, actual measured concentrations of the contaminants that result in exposures above threshold values appear to be present in media at concentrations less than modeled concentrations. Assessment of measured concentrations of antimony (the contaminant with the greatest exposure) in the Midlothian drinking water supply system results in a HQ of 0.05 rather than the HQ of 3 based on modeling concentrations. Also, actual measured concentrations in soil of antimony and cadmium for which exposures exceed threshold levels are less than modeled concentrations in the area north of CSC (close to receptor points C1 and C3). The measured and modeled concentrations are compared in Table 2 along with background concentrations. The fact that the measured concentrations are approximately 60 times less than the modeled concentrations is particularly interesting given that CSC has been operating since 1975 (20 years to date), TXI has been burning waste-derived fuel since 1987 (9 years to date), and the risk assessment considers emissions for 30 years. Due to the linear relationship of deposition over time, this implies that risk estimates may be conservative by an order of magnitude for some contaminants.

Region 6 currently can find no basis for federal regulatory action in response to a mercury HQ of 1. There is no basis for action because of the conservatism and uncertainty associated with the risk assessment method, and because the measured media concentrations of mercury are within the range of U.S. background concentrations of mercury. Region 6 is currently unable to judge the viability of estimated mercury exposures as with HQs greater than or equal to 1 due to uncertainties in the method. In addition, TNRCC has stated in its *Critical Evaluation of the Potential Impact of Emissions from Midlothian Industries: A Summary Report* (1995) that concentrations of mercury in the Midlothian area are equal to or lower than local and U.S. background levels.

Table 2. Comparison of Modeled and Measured Concentrations

Contaminant	Modeled Soil Concentration (mg/kg)	Measured[6] (mg/kg)	Local Background (mg/kg)	U.S. Background (mg/kg)
Antimony	6.3	<3	<MDL	<1 - 8.8
Cadmium	11 - 50	< 0.095 - 3.6	<MDL-0.5	0.01 - 7
Mercury	0.38	<1.0	<MDL	<0.01 - 4.6

[6] Measured values obtained from TNRCC's recent *Critical Evaluation of the Potential Impact of Emissions from Midlothian Industries: A Summary Report,* and CSC's *Analytical Results - Off-Site Investigation, Chaparral Steel, Midlothian, Texas.*

Some citizens and organizations may still be concerned with emissions from the four facilities despite the fact that the models and exposure scenarios used in this analysis are conservative and Region 6 determined that actual cancer risks and non-cancer health effects are below regulatory levels of concern. It may be of interest to local and state governments to identify the predominant source(s) of theoretical risks from the four industries. The predominant sources of risk from the four industries can be evaluated by comparing the emission rates and the unit combined deposition and air concentrations associated with each facility. The unit combined deposition rate and air concentrations associated with each emission source are compared in Table 3 for point C3. Emission rates are compared in Table 4.

Table 3. Comparison of Unit Deposition Rates and Air Concentrations at Point 3

Facility	Unit Combined Deposition (g/m^2-yr) per 1 g/sec	Unit Air Concentration ($\mu g/m^3$) per 1 g/sec
CSC Fugitives	30.8	18
CSC Baghouse A	0.320	0.37
CSC Baghouse B	0.080	0.06
CSC Baghouse C	0.078	0.063
NTCC	0.005	0.006
TXI	0.012	0.013
Holnam	0.001	0.001

As noted in Table 3, the deposition rate of contaminants from CSC are at least an order of magnitude greater than the contaminant deposition rate associated with the cement kilns. CSC's fugitive emissions overwhelm all other deposition rates by two to three orders of magnitude while Holnam's and NTCC's deposition rates at point C3 are almost negligible. TXI's deposition rate at this location is greater than Holnam's and NTCC's, yet still significantly less than CSC's deposition rates.

Table 4. Comparison of Emission Rates

Constituents	Chaparral	NTCC	TXI	Holnam
	Estimated Representative (g/sec)	Estimated Representative (g/sec)	Estimated Representative (g/sec)	Estimated Representative (g/sec)
Antimony	2.97×10^{-2}	9.09×10^{-5}	1.60×10^{-4}	NA
Arsenic	1.89×10^{-4}	1.07×10^{-5}	2.13×10^{-4}	9.00×10^{-5}

Constituents	Chaparral	NTCC	TXI	Holnam
Barium	NA	2.65×10^{-5}	4.03 x 10-3	8.82×10^{-4}
Beryllium	NA	1.77×10^{-6}	2.08×10^{-4}	2.00×10^{-5}
Cadmium	3.02×10^{-3}	5.18×10^{-4}	6.50×10^{-4}	NA
Chromium VI	3.78×10^{-4}	2.65×10^{-5}	9.80 x 10-9	1.11×10^{-5} (total)
Lead	5.85×10^{-2}	4.17×10^{-3}	1.43 x 10-2	8.00×10^{-5}
Mercury	1.06×10^{-5}	4.67×10^{-4}	3.01×10^{-4}	2.52×10^{-4}
Nickel	7.68×10^{-3}	2.78×10^{-5}	3.01×10^{-4}	3.78×10^{-4}
Silver	NA	8.96×10^{-5}	5.33×10^{-5}	NA
Thallium	NA	1.26×10^{-5}	5.04×10^{-4}	2.00×10^{-5}
Zinc	5.96×10^{-1}	5.43×10^{-6}	2.69×10^{-3}	8.82×10^{-4}

Likewise, the unit air concentrations associated with emissions from CSC are at least 100 times greater than those associated with NTCC and Holnam. The level of CSC's baghouse emissions on contaminant air concentrations at this location is six times the level of TXI, the next most significant source. The level of CSC's fugitive emissions is 1,000 times the level TXI's emissions.

A comparison of the emission rates between the four facilities in Table 4 again shows that CSC's emissions of antimony and cadmium dominate that of the other facilities. CSC's estimated emissions of antimony are 186 times that of TXI and CSC's emissions of cadmium are almost five times that of TXI.

Thus, it is clear that the majority of the potential for theoretical noncancer health effects associated with antimony and cadmium result from CSC, not the cement manufacturing facilities.

4. RECOMMENDATIONS REGARDING DATA GAPS

The data obtained for this screening level risk assessment were sufficient to meet the objective of the study which was to assess the protectiveness to human health of permit operating conditions. The study concluded that there are no cancer risks or non-cancer health effects above regulatory levels of concern associated with permitted burning of hazardous waste at TXI. Thus, there are no recommendations regarding data gaps to present.

5. LITERATURE CITATIONS

General Information

4 USGS quadrangle maps (Cedar Hill, Britton, Venus, Midlothian).

Camp, Dresser, and McKee. 1989. *Watershed Management Study: Lake Michie and Little River Reservoir Watersheds.* Prepared for the County of Durham, NC.

Document entitled *Location of Known Commercial Animal Operations in the Midlothian Area.*

Draft table entitled *Emissions Estimates*. This table was prepared by the TNRCC and describes the rationale behind their selection of emission rates that are different from the rates recommended by TNRCC permit engineers in memorandums dated March 20 and April 12, 1995 (see list of items for NTCC and TXI below).

Dravo Corporation. 1976. Managing and Disposing of Residues from Environmental Control Facilities in the Steel Industry. Prepared for the U.S. EPA Office of Research and Development. Contract Number R-803619.

Geological Survey Planimetric Map, Cleburne, Texas

Geological Survey Planimetric Map, Corsicana, Texas

Geological Survey Planimetric Map, Dallas, Texas

Geological Survey Planimetric Map, Ft. Worth, Texas

Geraghty, J.J, D.W. Miller, F. Van Der Leeden, and F.L. Troise. 1973. *Water Atlas of the United States*. Water Information Center, Inc., NY.

Hites, R.A., and S.L. Simonich. 1994. Vegetation - Atmosphere Partitioning of Polycyclic Aromatic Hydrocarbons. *Env. Sci. Tech*. Vol. 28 No.5.

Jindal, M. and D. Reinhold. 1991. Development of Particulate Scavenging Coefficients to Model Wet Deposition from Industrial Combustion Sources. Paper 91-59.7. Annual Meeting - Exhibition of Air and Waste Management Association, Vancouver, BC. June 16-21, 1991.

Memorandum, from U.S. EPA\ORD, to Addressees. January 20, 1995.

PEI Associates, Inc. 1986. *Air Quality Modeling Analysis of Municipal Waste Combustors.* Prepared for the U.S. Environmental Protection Agency, Monitoring and Data Analysis Division, Research Triangle Park, NC.

Real Estate List (computer printout) for the Midlothian ISD, dated April 25, 1995. This report was developed by the Ellis County Appraisal District and specifies property owners in the area that have proven that their property is used for agricultural or ranching purposes. Code "D1" is a ranch and code "D3" is a farm.

Research Triangle Institute. 1993. Detailed Summary of Information Collection Request Responses for Electric Arc Furnace (EAF) NESHAP. Prepared for U.S. EPA Office of Air Quality Planning and Standards.

Texas Department of Health, Division of Milk and Dairy Products, Establishment Report dated April 24, 1995.

TNRCC draft report section entitled *Selection of Receptors for TXI* dated April 4, 1995.

TNRCC, 1995. *Critical Evaluation of the Potential Impact of Emissions from Midlothian Industries: A Summary Report.* Office of Air Quality/Toxicology and Risk Assessment Section. Austin, TX.

U.S. EPA, 1989. Risk Assessment Guidance for Superfund. Office of Emergency and Remedial Response. Washington, DC. EPA/540/1-89/002.

U.S. EPA. 1990. *Exposure Factors Handbook.* Office of Health and Environmental Assessment, Exposure Assessment Group. Washington, D.C. March.

U.S. EPA. 1990a. Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustion Emissions. Interim Final. Office of health and Environmental Assessment/Office of Research and Development. EPA/600/6-90/003.

U.S. EPA. 1993. "Report to Congress on Cement Kiln Dust." OSWER. EPA/530-R-94-001. December.

U.S. EPA, 1994. Guidance for Performing Screening Level Risk Analysis at Combustion Facilities Burning Hazardous Waste. Office of Emergency and Remedial Response/Office of Solid Waste, Washington, DC.

U.S. EPA. 1994a. *Estimating Exposure to Dioxin-like Compounds. Review Draft.* Office of Research and Development. Washington D.C. June. EPA/600/6-88/0055C.

U.S. EPA. 1994b. Mercury Study Report to Congress, Office of Air Quality Planning and Standards and Office of Research and Development, Research Triangle Park, NC and Washington, DC.

U.S. EPA. 1994d. *User's Guide for the Industrial Source Complex Dispersion Models*. Office of Air Quality Planning and Standards, RTP, NC. Draft.

U.S. Department of Commerce. 1992. International Station Meteorological Climate Summary CD ROM.

Van der Leeden, F., F.L. Troise, and D.K. Todd. 1990. *The Water Encyclopedia*. Lewis Publishers, Chelsea, MI.

Chaparral Steel

Dispersion Modeling of Emissions from Large Section Mill Reheat Furnace (prepared by Forsite Corporation for Chaparral Steel) dated November 1989.

Letter and enclosures from Chaparral Steel Company to Region 6 dated May 8, 1995, responding to the Region's request for information about the emission of contaminants from Chaparral's facility.

Unsolicited letter and enclosures from Chaparral Steel Company to Region 6 dated December 20, 1995. Enclosure entitled *Ambient Monitoring Program* contains concentrations of contaminants in Chaparral's baghouse dust.

Unsolicited letter and enclosures from Chaparral Steel Company to Region 6 dated January 16, 1996. Enclosure entitled *Analytical Results - Off-Site Investigation* contains results of the analysis of soil samples collected from the area immediately north of Chaparral Steel Company.

New/Modified Source Technical Review (prepared by TNRCC) dated May 22, 1992.

TACB Mini Emissions Inventory Report (for Chaparral) from the Point Source Database dated May 2, 1995.

Texas Natural Resource Conservation Commission (TNRCC) Air Permit dated February 22, 1994.

Holnam Texas, L.P.

A letter from Holnam to TNRCC regarding the previous letter regarding dioxin emissions submitted by its consultant Trinity. The letter corrects the emission rates identified in the Trinity letter to account for sample dilution.

Letter from Holnam Texas, L.P. to Region 6 dated May 19, 1995, in response to Region 6's request for information regarding emission rates.

Letter summarizing dioxin data from Trinity Consultants to TNRCC dated November 12, 1993.

Selected portions of Holnam's (known as BoxCrow Cement Co. at the time) application to amend their air permit dated November 1992 prepared by Trinity Consultants.

TACB Mini Emissions Inventory Report (for Holnam) from the Point Source Database dated May 2, 1995.

TNRCC Air Permit for Holnam - Maximum Allowable Emission Rates. Permit number 8996 and PSD-TX-454M1. September 26, 1994.

TNRCC Air Permit for Holnam - Special Provisions. Permit number 8996 and PSD-TX-454M2. April 26, 1994.

North Texas Cement Company (NTCC)

Appendix III.A., RCRA Part B Permit Application entitled *General Engineering Report for North Texas Cement Company*.

Copies of Tables 21-24 summarizing results of dioxin testing conducted November 7-9, 1991.

Draft Table 2.2 dated May 2, 1995, entitled *NTCC Emission Estimates Used in the Final Risk Assessment*. (This will eventually be used in TNRCC's risk assessment report. However, be advised that Industry states that table contains an error with regard to emissions rates for As, Be, Hg and Cr. TNRCC developed the emission rates based on permits limits in lb/hr but incorrectly adjusted data to gram/sec).

Excerpt from a BIF test report entitled *Semivolatile/PAH Data, June 1992 BIF Test.* Excerpt includes test data from Test 2, Runs 1-3. Analyses were conducted July 19, 1992.

Excerpt from the NTCC Trial Burn Report that provides information about contaminant concentrations in NTCC's CKD.

Pages II-1 through II-12 of a risk assessment protocol prepared by NTCC. This information was provided to EPA during a meeting on May 8, 1995 with Bill Wilson of NTCC. The emission rates identified in Table II-1 are the rates NTCC believes should be used to support the risk assessment.

TACB Mini Emissions Inventory Report (for NTCC) from the Point Source Database dated May 2, 1995.

TNRCC memorandum dated March 20, 1995 from Michael Koenig to Lucy Fraiser regarding emission estimates for TNRCC's NTCC risk assessment.

TNRCC's, 1995. *North Texas Cement Company (NTCC) Modeling Approach to Risk Assessment Screening Analysis*, April 21, 1995.

Texas Industries, Inc. (TXI)

Copy of draft Table 2.2 dated May 2, 1995, entitled *TXI Emission Estimates Used in the Final Risk Assessment.* (This table will eventually be used in TNRCC's risk assessment report.)

Copy of TNRCC's draft *Texas Industries, Inc. (TXI) Modeling Approach to Risk Assessment Screening Analysis* dated April 24, 1995.

Copy of TXI's draft *Protocol for a Comprehensive Risk Assessment for the Texas Industries Facility, Midlothian, Texas* dated July 15, 1994.

Copy of draft memorandum from Paul DeCiutiis to Lucy Fraiser, dated April 12, 1995, regarding emission estimates for TNRCC's TXI risk assessment.

Copy of selected portions of Part B Permit Application (Section 5.0 [contains modeling and stack parameter/test data information]).

Copy of selected portions of *Trial Burn Report* (Volume 1, Chapter 1).

Copy of Adjacent Landowners Map identified as Figure I.G.1. The source of this information is unknown.

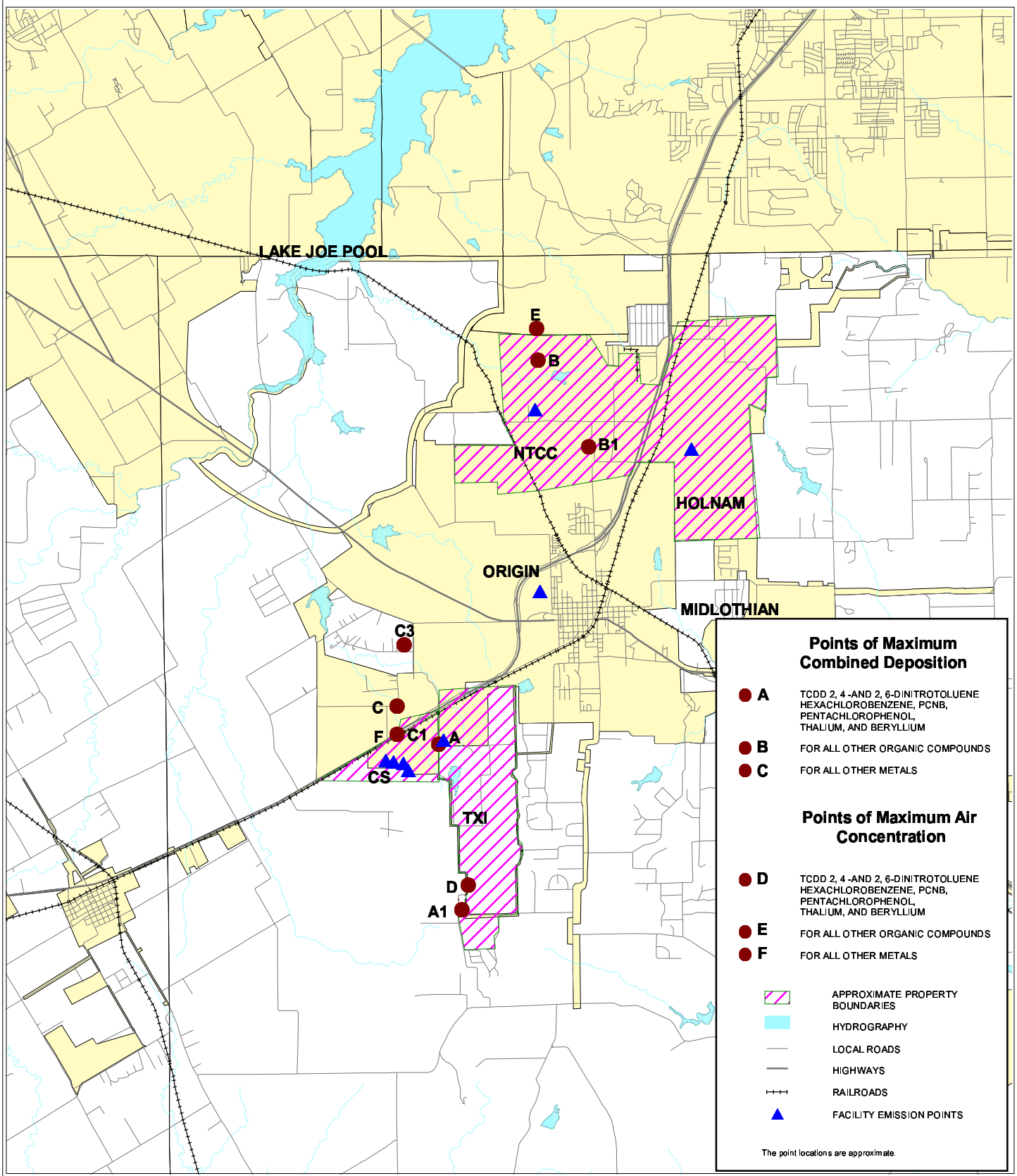
Excerpt from the TXI Trial Burn Report that provides information about contaminant concentrations in TXI's CKD.

Section 1 of Part B Permit Application. Contains facility background and land use information.

TNRCC Air Permit for TXI - Special Conditions. Permit Number 1360A. February 28, 1995.

TNRCC air Permit for TXI - Emission Sources - Maximum Allowable Emission Rates. Permit Number 1360A. June 6, 1994.

MAP1:
Points of Maximum Combined Deposition and Air Concentration



Source: RTI

0 0.7 Miles

N

A C S

Region 6
GIS Support Group
12-06-99
19991206SR01

APPENDIX F

References Concerning Risk Characterization

American Industrial Health Council (AIHC) (1992) Improving Risk Characterization, American Industrial Health Council, Washington, DC, 25 pages.

American Industrial Health Council (AIHC) (1995) Advances in Risk Characterization, American Industrial Health Council, Washington, DC, 11 pages.

Browner, C. (1995) *Risk Characterization* Memorandum issued March 21, 1995 (Note: Found in Appendix A of this Handbook).

Commission on Risk Assessment and Risk Management (CRARM) (1997) *Framework for Environmental Health Risk Management*, Final Report Volume 1, Washington, DC.

Commission on Risk Assessment and Risk Management (CRARM) (1997) *Risk Assessment and Risk Management in Regulatory Decision-Making*, Final Report Volume 2, Washington, DC.

Habicht, F.H. (1992) *Guidance on Risk Characterization for Risk Managers and Risk Assessment Memorandum*, Washington, DC.

National Research Council (NRC) (1983) *Risk Assessment in the Federal Government: Managing the Process*, Washington, DC: National Academy Press, March 1983.

National Research Council (NRC) (1994) *Science and Judgment in Risk Assessment*, Washington, DC: National Academy Press.

National Research Council (NRC) (1996) *Understanding Risk: Informing Decisions in a Democratic Society*, eds. Paul C. Stern and Harvey V. Fineberg, Washington, DC: National Academy Press.

U.S. Environmental Protection Agency (USEPA) (1984) *Risk Assessment and Management: Framework for Decision Making*, EPA 600/9-85-002, Washington, DC: U.S. Environmental Protection Agency, December 1984.

U.S. Environmental Protection Agency (USEPA) (1997), *Guidance on Cumulative Risk Assessment. Part 1. Planning and Scoping*, Science Policy Council, Washington, DC, July 1997.

U.S. Environmental Protection Agency (USEPA) (1998) *Risk Assessment Guidance for Superfund: Volume I -- Human Health Evaluation Manual (RAGS/HHEM)*, Washington, DC: U.S. Environmental Protection Agency, January 1998.

U.S. Environmental Protection Agency (USEPA) (1998) *EPA's Rule Writer's Guide to Executive Order 13045: Guidance for Considering Risks to Children During the Establishment of Public Health-Related Standard*, Interim Final Guidance, Washington, DC.

U.S. Environmental Protection Agency (USEPA) (2000) *Science Policy Council Handbook: Peer Review, 2nd Edition*, EPA 100-B00-001, Washington, DC: U.S. Environmental Protection Agency, December 2000.

References of EPA Risk Assessment Guidelines

Guidelines for Carcinogen Risk Assessment. Federal Register 51: 33992-34003, 24 September 1986; also EPA Publication No. EPA/600/8-87/045, August 1987.

Proposed Guidelines for Carcinogen Risk Assessment; Notice. Federal Register 61: 17960-18011, 23 April 1996.

Guidelines for Mutagenicity Risk Assessment. Federal Register 51: 34006-34012, 24 September 1986; also EPA Publication No. EPA/600/8-87/045, August 1987.

Guidelines for the Health Risk Assessment of Chemical Mixtures. Federal Register 51: 34014-34025, 24 September 1986; also EPA Publication No. EPA/600/8-87/045, August 1987.

Guidelines for Developmental Toxicity Risk Assessment. Federal Register 56: 63798-63826, 5 December 1991.

Guidelines for Exposure Assessment. Federal Register 57: 22888-22938, 29 May 1992.

Guidelines for Reproductive Toxicity Risk Assessment; Notice. Federal Register 61: 56274-56322, 31 October 1996.

Assessment of Thyroid Follicular Cell Tumors. EPA Publication No. EPA/630/R-97/002, March 1998.

Guidelines for Ecological Risk Assessment. Federal Register 63: 26846-26924, 14 May 1998; also EPA Publication No. EPA/630/R-95/002F, April 1998.

Guidelines for Neurotoxicity Risk Assessment; Notice. Federal Register 60: 26926-26954, 14 May 1998.

Guiding Principles for Monte Carlo Analysis (contains: Policy for Use of Probabilistic Analysis in Risk Assessment at the U.S. Environmental Protection Agency). EPA Publication No. EPA/630/R-97/001, March 1997.

NOTES AND COMMENTS